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THE GENETICS OF CONGENITAL PYLORIC STENOSIS

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Congenital pyloric stenosis is a condition which usually becomes manifest about the fourth week after the patient's birth. The symptom of projectile vomiting with constipation and the signs of pyloric tumor and gastric peristalsis are occasioned by anatomical changes which can only be observed if the case is surgically treated or examined at autopsy. The essential feature of the disease, muscular hypertrophy of the pylorus, is a structural change, probably present before birth for it has been identified in a stillborn child and a seven months' foetus (Strachaner 1927). The disease has a low familial incidence and, though several pedigrees have been published which show more than one affected child, the mode of inheritance is uncertain. Cautley and Dent (1902) reported instances of the disease in a great aunt and her nephew and a family with three affected sibs was mentioned by Heubner (1906). There are other early records of more than one case in a family (Freund, 1903, Grissen, 1904, Ashby, 1907, and Rosenhaupt, 1907). Still (1915) pointed out that in a series of 94 cases there were three pairs of affected sibs and Finkelstein (1924) recorded one family with four and another with three sibs affected. A brother and sister, both affected, whose father may also have had pyloric stenosis in infancy, were described by Caulfield (1926), and Ashton (1929) found an authentic example of mother and son both affected. Cockayne (1934) published two pedigrees, each with a pair of first cousin patients. The case of a male patient, whose brother's son and daughter and whose sister's two sons developed the same condition, was reported by Halbertsma (1935). De Lange (1936) put on record a family of a female patient whose sister's twin sons were also patients. Fabricius and Vogt-Moller (1937) described the case of a normal woman who had three affected children by her first husband and four by her second. Four pedigrees were investigated by Cockayne (1938): in one there was an affected pair of second cousins, in two pedigrees there were pairs of first cousin patients and, in the other family, there was a pair of affected first cousins, of whom the mother of one and the sister of the other suffered from vomiting during the first weeks of life.

Evidence in favor of hereditary influence in the causation of the disease has been obtained from the study of twins. Indeed, Ford, Brown and McCreary (1941) consider twining to be unduly frequent among affected cases. When the twins are binovular, it is usually found that if one is affected the other is normal; except in one instance (Sheldon, 1938) monovular twins are equally affected.

When a series of hospital cases of congenital pyloric stenosis is examined with respect to the birth order of the patients, it is regularly found that between 40 and 60 per cent are the result of first pregnancies: for example, Still (1929) found that

48.5 per cent were first born in 400 cases. The inference that primogeniture is a causal factor has been accepted by many authorities (Ford, Ross and Brown 1941) but not all (Bell and Fitsgibbon, 1934). Since the statistical proof is not easy, a further investigation on this point is not, perhaps, out of place. Pearson (1914), for example, asserted that primogeniture was a cause of quite a number of physical and mental defects: in some cases, later investigators have shown that his conclusions cannot be upheld (Thurstone and Jenkins, 1931). In order to establish beyond doubt that primogeniture is really a contributary cause of a condition, data would have to be collected to show that the children born after the patient were nearly always normal.

In the investigation described in this paper, an attempt was made to follow up, after a period of years, the families of undoubted cases of congenital pyloric stenosis. It was hoped, by this means, to obtain adequate data on which the influence of primogeniture might be accurately estimated. Unfortunately, the birth rate, during the period of the investigation, was declining and the following up of the families only discovered a very small number of brothers and sisters born after the patients. Nevertheless, the results of the investigation, though not absolutely conclusive, are of value in suggesting the probable aetiology of the condition.

The investigation was spread over a period of about five years. Most of the patients, who were the propositi of the study, had been treated in St. Thomas's Hospital, Great Ormond Street Hospital for Children, in London, England. The writers are indebted to a large number of helpers, among whom Miss D. E. Newlyn and Dr. D. M. Kapp should be specially mentioned.

Great difficulties were encountered in following up cases after long intervals. It was originally planned that the average interval between the operation and the visit to the family would be ten years: in fact the average interval was 6.66. The total number of propositi with unpublished pedigrees available for study was 434 but only 212 families were actually visited. Attempts made to visit the families of about 150 patients were unsuccessful. In rural districts, nearly all the families could be traced, but less than half of those who had lived in cities.

In the sibships of the 212 visited families (Series A), there were 221 affected children, of whom 185 were males, and 36 females. The diagnosis was confirmed at operation or autopsy in all cases except ten, eight males and two females, in whom the condition was medically treated. Of the children treated by operation, 130 males and 34 females were surviving at the time of the visit: five males had died of intercurrent diseases. In a number of the surviving cases, some abdominal disability remained, but the great majority appeared to be quite healthy. Of the ten medically treated cases, two males and two females died at the age of four months or under. The propositi, whose homes were not visited, (Series B), numbered 222 and in their sibships were altogether 228 affected children. Of these, 201 were males, 26 females, and one of unknown sex. In all, 386 out of 449 patients were males, i. e., 86.0.

THE GENERAL FEATURES OF THE VISITED FAMILIES (SERIES A)

In the 212 families, whose histories are summarized in the appendix, there were 528 children who were known to be either affected or unaffected (Table I). There were also 53 children, whose state with respect to the disease in question could not be ascertained: of these, 26 miscarried, 13 were stillborn or died at birth, and 14 died in infancy. The average number of children per family in the data is, therefore, less than three. The value of the data for deciding whether or not primogeniture is an aetiological factor depended a great deal on the number of normal or affected children born in the interval between the patient's operation and the visit. This number, 132, was disappointingly small. Some of the parents who were interviewed admitted that they had deliberately limited the family after

the patient's operation because of the fear that another child might have to undergo the same treatment.

The familial incidence of the condition is low but the disease is rare enough to make it likely that, if two affected children are found in the same sibship, this is not due to coincidence. In Series A, there were seven families with two children affected (See families Nos. 24, 68*, 119, 126, 167, 188 and 199*) and one family with three children affected (See No. 107). Further evidence of familial concentration was obtained by investigating near relatives. Two pairs of propositi were first cousins of one another (See Nos. 37 and 150, 148 and 164): four other patients each had a cousin affected (See Nos. 31, 63, 104 and 181). In addition to this definite familial incidence, there were doubtful histories of congenital pyloric stenosis in one mother, three brothers, one sister, one uncle and one cousin: for purposes of analysis these were counted as unaffected. In taking the family histories, attention was paid to the incidence of diseases of the alimentary tract, such as peptic ulcer, cholecystitis, peritonitis and cancer of the stomach. Four fathers and four mothers had definite histories of gastric or duodenal ulcer, there were also nine such histories among grandparents and four among patients' uncles. Appendicitis, peritonitis or ulcerative colitis were recorded in 13 parents, three sibs and five grandparents. Nine grandparents died of cancer in the alimentary tract.

TABLE I

SIBSHIPS (SERIES A) WHICH CONTAIN AT LEAST ONE CASE OF CONGENITAL PYLORIC STENOSIS: NUMBER OF CHILDREN

	Born before Propositus	Propositus	Twin of Propositus	Born after Propositus	Total
Affected Male	.....	178	2	5	185
Affected Female	.....	34	0	2	36
Unaffected Male	90	.....	1	73	164
Unaffected Female	88	.....	3	52	143
Total	178	212	6	132	528
(Miscarriages, Stillbirths, etc.)	(34)	(—)	(0)	(19)	(53)

There appears to be a slight tendency for patients to possess structural abnormalities other than pyloric stenosis: two patients (See Nos. 20 and 95) had hare lip and cleft palate, and in the family where three sibs were affected (No. 107), all three had abnormal conformation in the premaxillary region. One patient had a congenital heart lesion (No. 54) and one had club feet (No. 190). Mental disease was a rare complication; one subject was an idiot (No. 52), one was an imbecile (No. 104) and two were mentally retarded (Nos. 62 and 189).

Among the members of the families who were believed not to have congenital pyloric stenosis, there were seven cases of hare lip or cleft palate; one father (No. 7), three sibs (See Nos. 7, 74, and 162) and three other relatives. One brother had a congenital heart lesion (No. 90) and a sister in the same family had oesophageal stenosis. One sister (No. 162) had congenital absence of abdominal wall and another (No. 15) was simply stated to have been "deformed." A cousin (See No. 21) died of rectal atresia and another (See No. 168) had congenital intestinal

*In these families, the affected pair were twins, but whether monovular or binovular could not be ascertained.

obstruction. Some of these structural abnormalities may have a genetic relationship to congenital pyloric stenosis. The occurrence of blue sclerotics and brittle bones in patient and mother (No. 131) may have been quite unconnected with congenital pyloric stenosis. Very few cases of mental or nervous disease were found among near relatives.

The parents in four families (Nos. 12, 75, 129 and 134) were first cousins and in two families (Nos. 56 and 70) they were second cousins. There was an example also of a related case with first cousin parents in family No. 31. This incidence of first cousin marriages among parents of ascertained cases of congenital pyloric stenosis in Series A is significantly in excess of random expectation (Table II).

TABLE II

PARENTAL CONSANGUINITY

	Number with First Cousin Parents	Number with Second Cousin Parents	Total Number
Propositi and their Sibs (Series A).....	4	2	221
Other Relatives (Series A).....	1	0	4
Totals (Series A).....	5	2	225
Expected Totals with Standard Errors....	1.37±1.17	0.45±0.67	225
Propositi and Sibs (Series B).....	1	1	228
Totals (Series A and B).....	6	3	453
Expected Totals* with Standard Errors...	2.76±1.66	0.91±0.95	453

*A survey of 34,625 general hospital patients conducted by the Human Genetics Committee of the British Medical Research Council obtained the estimates 0.61% for first cousin parents and 0.20% for second cousin parents.

THE GENERAL FEATURES OF THE UNVISITED FAMILIES (SERIES B)

The 222 propositi in Series B provided some useful supplementary information, though in many aspects incomplete. In these sibships, 353 children were classified as affected or normal: there were also 16 stillborn sibs or miscarriages. Each propositus was, of necessity, the last to be born in the sibship. In six families, a sib was known to have been affected. Five patients had normal twin sibs. One patient suffered from hypospadias and left inguinal hernia in addition to pyloric stenosis and another suffered from achyluric jaundice. An unaffected sib of one propositus had a cleft palate and hare lip. Duodenal ulcer was diagnosed in the father of one patient.

The maternal grandmothers of one male patient were sisters and the parents of another were second cousins. The recorded incidence of consanguinity in the patients in Series B is thus not abnormal.

PRENATAL ENVIRONMENT

The examination of the effect of maternal age in cases of congenital abnormality sometimes reveals the presence of prenatal causes which would otherwise be unsuspected. The mean maternal age at birth for the 221 subjects with congenital pyloric stenosis in Series A was 28.77 years and for 220 subjects in Series B the mean was 27.73 (maternal age was unknown in eight instances in Series B). A reconstruction of the data in Series A, on the assumption that an affected person would be equally likely to occur at any of the maternal ages found in his sibship,

yielded the value of 28.06 years for the expected mean maternal age. The difference between the observed and the expected values are not significant and the result does not indicate that maternal age is an aetiological factor here. Paternal age was also found to be normal.

Of 221 cases in Series A, 109 were the results of first pregnancies. In Series B, 141 cases were first born, out of the total number 228. The large percentages of firstborn cases, 49.3 and 61.9 in A and B respectively, support the view that primogeniture is a significant aetiological factor. Caution is needed in accepting such a conclusion, however. In a recent survey of a very large series of births in Liverpool Maternity Hospital, Malpas (1937) showed that the expected proportion of first pregnancies was 46 per cent. It was admitted that the percentage might be unduly high because primiparae are more likely to be delivered in hospital than multiparae. The proportion of firstborn children in the general population depends upon the mean size of the family in the community and this is difficult to estimate. In particular, as Greenwood and Yule (1914) have shown, families selected by the presence of at least one affected member give an erroneous impression of the size of the family in the general population. The average size of sibships so selected tends to be too large. In a recent investigation of the families of mentally defective patients (Penrose, 1938), the number of births, including miscarriages, per sibship in the general community, estimated by the method of Greenwood and Yule, was 3.38. According to this estimate, the expected proportion of firstborn children should be one in 3.38 or 28 per cent: if this estimate is correct, the proportion of cases of congenital pyloric stenosis who are firstborn is significantly high. There are, however, two other factors which have to be considered. Congenital pyloric stenosis is a familial disease and it is one which may cause family limitation as soon as the occurrence of the first case in the family has been recognized. These two factors both tend to increase the proportion of firstborn affected children in the sample.

Suppose, for instance, that the normal number of children, born in a family in the general community, is s. Assume also that a certain congenital disease causes family limitation so that no children are born after the affected member. Let the true proportion of affected to total numbers of children, in families liable to the disease, be r. The proportion (p) of affected children who are first born in the family will be found to be

$$\frac{r}{1-(1-r)^s}$$

If, for example, a rare recessive condition causes family curtailment, the value of r is one quarter, p (the proportion of firstborn cases) has the value of 0.57 in a population where the normal sibship numbers two, a value of 0.43 where the normal sibship numbers three, and a value of 0.37 where the normal number is four children.

The mean size of family in the general population is not far above three and the known percentage of firstborn cases of congenital pyloric stenosis is about 0.50, this proportion would be of the right magnitude to agree with observation if the familial incidence (r) of congenital pyloric stenosis were about three-eighths. The evidence from the families investigated does not suggest that the manifest familial incidence can be nearly as high as this. By following up the 212 cases in Series A, who were the earliest affected in their sibships, 125 unaffected and seven affected children were ascertained (Table I). The propositi had four unaffected and two affected twin sibs. In Series B, there were five normal twin sibs of patients, 120 normal and six affected other sibs. It does not seem likely, therefore, that the manifest familial incidence can be far from one in twenty.

The ideal analysis of the comparative susceptibilities of the firstborn, second born, etc., to congenital pyloric stenosis could be carried out if all the families, in

which a case had occurred, were investigated about 20 years after the birth of the propositus. When the time interval between diagnosis and investigation is short, most of the cases are last born children and it is impossible, by the Yule-Greenwood method, to demonstrate any tendency for firstborn children to be affected. Instead of finding an excess of the observed number of affected firstborn over the expected number, when the interval is short, the method reveals a deficit. In the analysis of the present data, this deficit was seen unless the interval exceeded six years. In those families, which were investigated eight years or more after the birth of the propositus, there was a slight excess of the observed number of firstborn affected over expectation (Table III). The only way to obtain an idea of what the analysis would have revealed if the interval could have been longer was to extrapolate. This was feasible because the regression of size of family on length of interval since birth of affected child was found to be linear. If the average interval had been 10 years, the observed number of affected firstborn divided by the expected number of affected firstborn would have been 1.12. If the average interval had been 15 years, the ratio might have risen to 1.59 and, at 20 years, it might have risen to 4.45. Corresponding ratios were calculated for the second and third places in the

TABLE III

Number of Years Since Birth of Propositus	Number of Cases	Number of Cases which Result from First Pregnancies	
		Observed	Expected
0– 6	90	48	54.62
7	58	26	25.96
8–13	73	35	30.76
0–13	221	109	111.34

family and for the fourth to the ninth. In Table IV, the results of these calculations are shown. As no children are likely to be born more than 20 years after the birth of any propositus, the ratios in the bottom row of Table IV show the upper limit of the estimates for relative susceptibilities to congenital pyloric stenosis of children in the different birth ranks. The firstborn is perhaps about twice as likely to be affected as any child born afterwards, but is not more than six times as prone.

DISCUSSION ON THE MODE OF INHERITANCE

Two facts have been elicited by this enquiry. In the first place, there appears to be a definite familial incidence, which applies mainly to sibs and to cousins and which is small in magnitude. Secondly, the proportion of the patients with consanguinious parents exceeds random expectation. These facts taken together give reason for supposing that congenital pyloric stenosis is partly caused by a recessive Mendelian factor. Analysis of the data on the question of birth order is not conclusive but lends support to the assumption that the firstborn child is more likely to be affected than are the members of the sibship born later. Thus, the low familial incidence observed is not inconsistent with the hypothesis that the underlying causal factor is a recessive gene. A rare recessive trait should, indeed, be manifested in one quarter of the children in families which are prone to the disease. The observed familial incidence here, however, is only about one in twenty. If the firstborn were much more likely to be affected than other children, the familial

incidence would be much lower in large families than in small ones. This in fact, is the case in the present data. In Series A, apart from the two sets of affected twins, which are second born, in every family where more than one child is affected, one of them is firstborn. In the data of Series B, there are three instances of first and second, one of first and third, and one example of third and sixth children affected. The tendency to familial incidence is greatest at the beginning of the family. These considerations make it possible for a low familial incidence to be consistent with recessive diathesis as the underlying cause.

In the present data, as in previous work, a great excess of male over female patients is found: the males are about six times as numerous as the females. Among the unaffected sibs in Series A, however, the males exceeed the females, namely, 164 males to 144 females; in Series B there were 51 normal male sibs, 57 normal female sibs and 17 of unknown sex. Thus there were altogether 215 male and 201

TABLE IV

RATIOS OF OBSERVED TO EXPECTED NUMBER AFFECTED IN DIFFERENT BIRTH RANKS

The table is calculated upon the assumption that the increase of size of family with the lapse of time is linear.

Number of Years Since Birth of Propositus	Birth Rank		
	1st	2nd to 3rd	4th to 9th
0	0.82	1.17	6.19
5	0.93	0.96	1.72
6.66*	0.98	0.92	1.46
10	1.12	0.85	1.17
15	1.59	0.78	0.95
20	4.45	0.74	0.84

*Mean interval in the data.

female normal sibs. This distribution does not favor the assumption that the excess of male patients is due to the action of sex linked genes. Moreover, inspection of pedigrees shows that transmission to a male patient must frequently take place through the father. There is also no evidence of partial sex linkage. It seems correct to assume that the male constitution has less resistance than the female constitution to the development of the disease. This explanation of the differential sex incidence helps to account for the low familial incidence observed.

On the hypothesis that a rare recessive gene is the underlying cause, the chance that any child is susceptible in a sibship, where the disease can occur, is usually one in four. If the degree of susceptibility of the firstborn male child is maximal, the chance of its being affected is one in four. The degree of susceptibility of a firstborn female or of a male not firstborn will be much less than this, and the female who is not firstborn stands very little chance of being affected. The manifest familial incidence of the disease in a family of three children, which mainly depends upon the chance of the occurrence of an affected firstborn male, will have a value not much greater than $\frac{1}{4}$ times the chance of being a male times the chance of being firstborn, i. e., $\frac{1}{4} \times \frac{1}{2} \times \frac{1}{3}$ or $\frac{1}{24}$. The observed familial incidence of $\frac{1}{20}$ is thus not in disagreement with the view that the predisposition has a familial incidence of $\frac{1}{4}$. The gene, moreover, must be commoner than the frequency of the disease in the general population would at first suggest. Hence, it is not unlikely that occasionally parent and child would both be affected.

The hypothesis that a recessive gene, whose manifestation is influenced by birth order and sex, is the cause of congenital pyloric stenosis can be used to interpret the presence, in certain families, of abortive cases and associated abnormalities. Some structural abnormalities found in patients may have been accidentally present, but others, like hare lip, cleft palate and intestinal atresia, may have been modified manifestations of the same underlying gene. It is conceivable, also, that some of the alimentary diseases in relatives may have been manifestations of the gene in the heterozygous form. Peptic ulcer, for example, like congenital pyloric stenosis, is more often found in males than in females and has been believed to be due to an irregularly dominant genetic factor (Levin and Kucher, 1934). In homozygous form, this factor might affect the same organ more severely and earlier in life. In support of this view, it may be recalled that ulcers of the duodenum associated with pyloric stenosis in infants have been recorded by several observers (Holt, 1913; Harrison, 1931).

SUMMARY

The families of 212 cases of congenital pyloric stenosis were investigated about 6½ years after the births of the propositi. In this way, nine more cases were discovered in the sibships, two of whom were twins of the propositi. The data were amplified by reference to 222 propositi whose families were not visited. The data are consistent with the hypothesis that the disease is a recessive diathesis. Males are more susceptible than females and the firstborn child is more susceptible than children born afterwards in the same sibship. The relationship of congenital pyloric stenosis to some other diseases is discussed.

APPENDIX

DETAILS OF 212 SIBSHIPS: SERIES A

N—Identification number of sibship.
A—Number of years between birth of first affected child and date of investigation.
B—Excess of father's age over mother's age.
C—Order of birth in sibship. The sex and maternal age at birth of each sib is shown in the appropriate birth rank. Affected children, who were living at the time of investigation, are indicated by underlining once. Affected children, who did not survive, are marked by double underlining.
All cases were surgically treated, except those marked thus: *.
Additional notes on the sibships can be found by reference to the identification numbers.

N	A	B	C 1	2	3	4	5	6	7	8	9	10
1	2	1	F 30									
2	5	5	F 21	F ..	M25	M27	M29	M30	M33			
3	1	2	....	M31								
4	6	2	M24									
5	3	0	M19	M22								
6	5	2	M22									
7	7	1	M25	M27	F 31	M33						
8	2	1	M28	M35								
9	2	?	F 23									
10	4	4	F 23	M24	F 27							
11	9	0	F 21	F 23	M27							
12	5	2	M27									
13	5	10	F 23	M27								
14	2	0	F 18									

N	A	B	C 1	2	3	4	5	6	7	8	9	10
15	2	—1	F ..	F 27	M30 F 30							
16	11	0	M..	M39								
17	4	0	M17	M19	F 24	M26	....	F 28	F 31	M33		
18	13	10	M19	F 22	M23	F 25	F 26	F 29	F 31	F 33		
19	2	6	M29	....								
20	0	7	M28									
21	2	1	M38									
22	9	0	....	F 29	M30							
23	5	0	M27	F 30								
24	5	0	M20	M22								
25	5	—2	M29	M32	F 41							
26	4	2	M23	M25								
27	4	5	F 32	M34								
28	9	1	F ..	M33								
29	1	0	M29									
30	4	1	M29	M35								
31	1	3	M27									
32	10	—3	F ..	....	M29	M35						
33	7	6	M22									
34	10	4	M23	F 24	M26	M33						
35	1	6	M29									
36	10	10	F 32	M33	M38							
37	2	7	M26	F 30	M39							
38	3	2	F 22	M25	M27							
39	2	—3	M28	M32	F 34	M35	M37	F 42	M44			
40	7	2	M38									
41	8	—1	F 25	M26	F 29	M31	M32	F 38				
42	8	5	M22	F 24	M27	F 31						
43	11	10	M22	F 24	M26	M28	M30	M34	M37			
44	5	4	F 29	M33								
45	3	3	M25									
46	3	2	M25									
47	12	12	F 29	F 32								
48	6	8	M22	F 24								
49	4	1	M26									
50	4	2	M22									
51	5	7	M21	25								
52	3	3	M29									
53	9	—1	M27	M32								
54	3	1	M25									
55	8	—1	M24	M27								
56	5	—1	F 25	M29								
57	8	—3	M33	M36								
58	10	10	M25									
59	8	5	F 28	F 31								
60	6	3	M24	F 27	M31							
61	6	10	F 41									
62	7	6	M34									
63	6	4	F 26	F ..	F 29							
64	7	—2	F 29									

N	A	B	C 1	2	3	4	5	6	7	8	9	10
65	6	0	F . .	M21	M25							
66	7	—6	M28	F 29	M31	F 35						
67	7	—?	M29	M31								
68	7	1	M21	M22 M22								
69	6	17	F 28									
70	7	1	F 29	M33	M35							
71	7	19	M28	M29	M32							
72	2	0	M28									
73	8	5	F 31									
74	6	7	M22	F 25								
75	7	1	M27	M28	M32							
76	6	10	F 34	M36	F 38	M43						
77	7	1	M26	M28	M31							
78	6	5	F 24	F 26	F . .	M29	M30					
79	8	2	F 26	M29								
80	8	3	M22	F 24								
81	8	1	M23									
82	7	1	F 19	F 22	M28	M34						
83	8	1	F 20	F 26	F 27	M29	F 31	M35	M37	M38	M40	. . . .
84	7	2	M30	M33	M37							
85	9	3	M21	F 23	M27	M30						
86	7	0	. . . .	M31	F . .	M38						
87	8	4	M28	F 29	F 32							
88	7	3	M23	M28	. . . .							
89	7	2	M23	F 27								
90	7	0	M . . F 29	M34	. . . .							
91	7	5	F 34	M36	M . .							
92	7	9	M19	F 25								
93	7	—1	M26	M28								
94	6	7	F 32	F 33	M34	M39						
95	8	—3	M33	. . . .	M38	M39						
96	6	0	F 23	M29	F 32	F 37						
97	6	5	F 17	M19	M24	M27						
98	6	1	M31									
99	7	—4	M33	M34	. . . .							
100	6	0	M21	F 24								
101	7	2	M21	M25	M29							
102	7	3	F 22	F 27	F 29							
103	6	3	M25									
104	7	2	F 24	F 25	. . . .	F 33						
105	6	10	F 23	F 28								
106	7	7	F 25	M26	F 29	F 31	M33					
107	10	4	F 24	. . . .	M27	F 29	. . . .					
108	7	—2	M38	. . . .								
109	7	—4	F . .	. . . .	M36							
110	7	1	F 30	M32								

N	A	B	C 1	2	3	4	5	6	7	8	9	10
111	6	—2	M32									
112	7	2	....	M35	F 39							
113	6	7	F 32	F 34								
114	6	0	M40	F 44								
115	6	1	F 26	M30								
116	5	1	M27									
117	7	9	F 23	F 24	F 27	M29	F 34					
118	7	2	M21	M23	F 25	F 29						
119	7	1	M22	M23	M26							
120	8	0	F 25	M27								
121	8	—6	M31									
122	6	0	M24	M27								
123	7	—1	F 23	F 26								
124	7	0	F 31	M38	F 40							
125	7	0	M20	F 26	F 29	M30	M32					
126	8	6	M23	M24	M26							
127	7	20	M39	F ..	....							
128	10	—2	M28									
129	7	5	M22									
130	10	—3	M33									
131	7	12	....	F 38								
132	10	0	F 25	M27								
133	8	—2	....	F 34	F 38							
134	10	0	F 33	M34	F 38							
135	10	—3	F 24	....	M31							
136	7	0	M28									
137	7	0	M23	F 26								
138	7	7	M29	M31								
139	7	—6	M32	F 34	F 36	....	F 39	M41				
140	10	0	M23									
141	7	1	F 24	M26								
142	7	1	M28	M31	F 38							
143	7	4	M31	M37								
144	7	—3	M26	M27								
145	10	2	M19	M26								
146	10	3	M23	F 24	M26	M28	F 30	M32	M34	M35	M38	
147	6	—2	M30									
148	4	—1	M23	M27								
149	5	4	M25									
150	7	3	M34									
151	8	3	F 25	F 27	M33							
152	7	1	M23	M25	M27	M30						
153	8	4	M25	M28	M31							
154	9	1	M23	M26	M28	M31	M34	....	M37			
155	5	5	M21	M27								
156	6	3	M19	....								
157	7	—1	M24	F 30								

N	A	B	C 1	2	3	4	5	6	7	8	9	10
158	8	0	M23	M25	M27	F 29	M31	M32	F 34	....		
159	5	8	M21	M30	M31							
160	7	—5	M30	F 31	M34	M37						
161	8	6	M22	F 29								
162	6	4	....	F ..	M28	M31						
163	8	1	M23	M25	M33							
164	7	0	M24	M30								
165	8	—1	M30	F 32	F ..	F 36	M38	F 40				
166	6	13	M20	F 22	F 23	F 27	.....	M34	M37			
167	13	2	M32	F 33	....							
168	10	4	M24	M27								
169	?	?	....	M34								
170	6	3	M23	M25								
171	4	8	M18									
172	4	1	M25	F 26	M30	M35						
173	4	3	F 28	M32								
174	4	6	M22	F 26								
175	11	0	M25	M27	M28	M29	....					
176	4	3	M16	F 18								
177	6	6	M25	M27								
178	6	2	M26									
179	7	1	F 31	F 35								
180	11	—1	F 22	M24	F 25	M28	F 30					
181	8	—2	F 28	M30	M39							
182	11	—7	M41	....								
183	9	23	M22	M.. / M..	M24	M26	F 28	M33				
184	8	—1	M29	M35								
185	11	4	M26 / F26	F 29	M33 / F 33							
186	8	0	F 19	F 22	M24	M27	F 29	F 32	F 34	F 36		
187	8	4	M17 / F 17	M19								
188	13	4	M19	F 23	M27	M29						
189	10	3	M21									
190	6	1	M22									
191	9	—8	M37									
192	3	7	M23	M24	M26	F 28	F 33	M35				
193	7	—1	M28									
194	8	—5	M33	F 34								
195	11	—2	M31	F 33								
196	2	5	M22									
197	5	8	M21	M22								
198	9	4	F 20	M22	M25	M29						
199	7	3	F ..	M28 / M28	F 34							
200	11	1	M..	M26	F 27							
201	4	3	M20	M22	M26	M34						
202	6	1	M27 / M27									

N	A	B	C 1	2	3	4	5	6	7	8	9	10
203	2	2	F 30	M35*								
204	1	1	F 22	M33*								
205	1	—2	M28*									
206	2	7	M25	....	....	M28*	F 29					
207	8	2	M25*									
208	9	1	M24*	F 27								
209	6	1	F 28*	M29								
210	9	4	M25	M26*	M28	M30						
211	10	1	F 35*	M37								
212	10	0	M22*	M23	F 25							

NOTES

2. C2—died at birth. Two sisters of mother—cleft palates.
3. C1—miscarriage at 4 months.
5. C1—died of measles at 10 months. Mother's cousin—Little's disease.
7. Father—cleft palate. C1—double hare lip.
9. Mother—history of vomiting in early infancy.
12. Father and mother—first cousins.
15. C1—stillborn, "deformed." C2—one twin died at one year of diarrhoea and vomiting.
16. C1—stillborn.
17. C5—miscarriage at 3½ months.
19. Mother—appendectomy at 19. C1—died at 7 weeks. C2—miscarriage at 1 month.
20. C1—hare lip and cleft palate, died at 4 weeks.
21. Mother's sister's son died at 1 week of atresia of rectum.
22. C1—miscarriage at 2 months.
27. Mother's mother—haemorrhage due to gastric ulcer.
28. Father—died at age of 40 of ulcerative colitis. C1—died at 1 day.
30. Father—appendectomy at 32. Mother—appendectomy at 31. C2—undescended testis.
31. Two children of 2 sibs of one of the father's grandparents were the parents of a male who was medically treated for pyloric stenosis.
32. C1—stillborn. C2—miscarriage at 3 months. Father's mother—died of cancer of the stomach.
36. C2—infantile paralysis at 14 months. C3—hemiplegic, but no history of febrile attack.
37. Father's sister's son—No. 150, C1.
38. Mother's mother—cholecystectomy.
39. Father's sister—cholecystectomy.
40. Mother—gross rachitic deformity. C1—born by caesarean section.
41. C1, C2, and C6—died of measles in infancy.
42. Mother's brother's son—medically treated for severe vomiting at 3 months.
45. Father—appendectomy at 28. Father's brother—died of cancer of the stomach.
46. Mother's brother—medically treated for severe vomiting in infancy.
49. Father—abdominal tuberculosis. Father's mother's father—died of cancer of rectum two children of his sibs died of cancer of stomach.
51. Father—pulmonary tuberculosis.
52. C1—idiot with small head.
54. C1—congenital heart lesion.
55. Father's father—died of cancer of stomach.
56. Father's mother and mother's father—first cousins. Father—duodenal ulcer; appendicectomy at 32. Father's mother—perforated gastric ulcer.
58. C1—hydrocoele at 2 years. Father's father—died of cancer of the oesophagus.
60. Mother—slight exophthalmic goitre.
61. Mother—duodenal ulcer at 42.
62. C1—mentally retarded.
63. C2—died at 2 months. Father's brother's son—treated medically for pyloric stenosis.
64. Mother—slight goitre.
65. C1—stillborn.
68. C2—both twins died at about 2 months.
70. Father's father and mother's father—first cousins. Mother—appendicectomy at 39.
71. C1—died at 10 weeks.
74. C2—hare lip. Father's father—gastrectomy for ulcer.
75. Father's father and mother's father—brothers. C1—died at 10 weeks. C2—recurrent vomiting from 2 to 5 years.

76. C2—died at 8 weeks.
77. C1—died of diphtheria at 5.
78. C3—"died at birth."
81. C1—died at 9 weeks.
82. C3—died of diphtheria at 4.
83. C2—appendicectomy at 14. C8—pulmonary tuberculosis. C4 and C5—died of diphtheria in childhood. C1—miscarriage. Father's father—died of cancer of the bowel. Mother's sister—cancer of the stomach.
84. C2—died at 8 weeks.
85. C1—died at 7 weeks.
86. C1—died at 2 months. C2—appendicectomy at 11. C3—died at 4 months of gastro-enteritis.
87. C1—died at 8 weeks.
88. C3—stillborn.
89. C1—died at 11 weeks.
90. C1—male twin died at 6 weeks of congenital heart. C2—died at 2 months. C3—died at 3 days of oesophageal stenosis.
91. C2—died at 13 weeks. C3—died at one month.
93. Mother—dyspeptic. C1—died at 8 weeks. Mother's brother—two operations for gastric ulcer.
95. C1—hare lip and cleft palate, died at 11 weeks. C2—stillborn.
97. Father—dyspeptic.
98. Father had attacks of abdominal pain.
99. C2—appendicectomy at 2 years. C3—induced abortion. Mother's sister—appendicectomy.
100. Father—appendicectomy at 23 years.
101. C3—hernia.
103. Mother—appendicectomy at 30. Mother's brother—appendicectomy.
104. C3—miscarriage. C4—imbecile with subthyroidism. Father's brother's son—congenital pyloric stenosis.
105. Father—duodenal ulcer at 40; perforated gastric ulcer at 43. Mother's brother—died of peritonitis.
106. C2—died of lymphosarcoma of thymus at 11. C5—died at 8 weeks.
107. Mother—appendicectomy at 30. C2—miscarriage at 3½ months. C5—miscarriage at 5½ months. C1, C3, and C4—very slight degree of cleft palate in each case. Father's father—died of cancer of stomach.
108. C2—miscarriage at 4½ months.
109. C1—died in convulsions at 4 days. C2—miscarriage at 3 months. Mother's mother—cholecystitis.
110. Mother—duodenal ulcer at 36.
111. Two of mother's nephews—appendicectomy.
112. C1—miscarriage. C2—died at 15 weeks. Mother's mother—died of cancer of stomach.
113. Mother—appendicectomy at 28; probably also gastric ulcer. Father's father—died of carcinoma of colon.
114. Father—chronic colitis. C1—died at 8 weeks. Mother's mother—died of cancer of stomach.
118. Mother—gastric ulcer at 16. C2—died at 9 months. C3—epileptic.
119. Father's mother—cholelithiasis. Father's mother's brother—hare lip.
120. Mother—umbilical fistula.
122. Mother's mother—gastric ulcer.
124. Father—appendicectomy at 40. C2—died at 7 weeks.
125. C4—died at about 2 months.
126. C1—died at 6 weeks. Father's brother—cancer of stomach. Mother's mother—duodenal ulcer.
127. C1—died at 6 weeks. C2—stillborn. C3—miscarriages. Mother's sister's daughter—died of appendicitis at 11.
129. Father's mother and mother's mother—sisters.
130. Mother's sister—gastric ulcer at 30.
131. Mother—bluish sclerotics: one tibia curved. C1—miscarriage. C2—blue sclerotics and brittle bones.
134. C2—died of diphtheria at 3½. Father's father and mother's father—brothers.
135. C2—stillborn. C3—died at 6 weeks.
136. C1—died at 9 weeks.
137. Father's sister—died of peritonitis at 17.
138. Mother's mother—died of subphrenic abscess.
139. C4—stillborn. C6—died at 13 weeks.
140. C1—died at 5 weeks.
141. C2—died at 10 weeks.

143. C1—died at 9 weeks.
145. Father's brother's son—peritonitis. Mother's brother—died of intussusception at 4.
146. C7—died at 6 months.
148. Father's sister's son—No. 164, C2. Mother's mother—gastric ulcer at 47.
149. C1—died at 11 weeks.
150. Mother's brother's son—No. 37, C3.
154. C3—died at 3 months. C6—miscarriage.
156. C1—died at 8 weeks. C2—miscarriage.
158. C8—miscarriage at 6 weeks. Father's mother—died of cancer of bowel.
159. C2—died at 4 weeks.
162. Father—pyloric ulcer at 32. C1—miscarriage. C2—abdominal wall malformed, died at 3 weeks. C4—abortive hare lip and cleft palate.
164. Mother's brother's son—No. 148, C1.
165. C3—stillborn.
166. C5—miscarriage.
167. C3—stillborn. Father's sister—appendicectomy.
168. Mother—appendicectomy at 14. Father's nephew or niece (whose parents were first cousins)—died of congenital intestinal constriction.
169. Mother—duodenal ulcer. C1—miscarriage. Mother's father—died at 67 of gastric ulcer.
170. Mother—hyperemesis gravidarum ar 24. C2—died at 4 weeks.
172. C4—died at 3 weeks.
175. C5—miscarriage.
176. C1—died at 4 months.
177. Father—exophthalmic goitre at 22. Father's brother—gastric ulcer.
178. C1—died at 9 weeks.
179. C1—died at 6 weeks.
180. C4—died of meningitis at 9 months. Mother's father—died of perforated ulcer in alimentary tract. Mother's mother—gastric ulcer. Mother's brother—duodenal ulcer.
181. Mother—goitre. Mother's brother's daughter—pyloric stenosis, medically treated. Mother's father—died of duodenal ulcer.
182. C1—died at 7 weeks. C2—miscarriage.
183. C2—one twin died at 2 months, the other at 2 days.
184. C1—hernia.
185. C1—died at 7 weeks.
186. Father—severe dyspepsia.
187. Mother's father—gastric ulcer.
188. C4—hernia.
189. C1—mentally dull.
190. C1—talipes.
192. C3—tuberculous peritonitis.
197. C1—died at 9 weeks.
198. C1—died at 9 weeks.
199. C1—died at 3 days. Father's sister—dyspeptic.
200. C1—died of wasting disease at 3.
201. C4—died at 10 weeks.
206. C2—miscarriage at 3 months. C3—miscarriage at 1 month.
209. C1—died at 4 months.
210. C2—died at 7 weeks.
211. C1—died at 3 months.
212. C1—died at 7 weeks.

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California Geology

This book is an attempt to interpret and make interesting for the general reader the technical knowledge of the complex geology of California.

The first three chapters are introductory, the author going to even greater lengths than a Chamber of Commerce in extolling the wonders of the Golden State. In the next four chapters the reader is oriented by following an 800-mile bee-line the length of the state, by considering the general behavior of rivers and the geologist's time-scale concept, and by having a "panoramic review" of the major events and processes in California's geologic history. Twelve more chapters deal each with a particular area. Three additional chapters consider petroleum, gold, and agriculture. The final chapter is 87 pages long. It conducts the reader along eight different automobile tours selected so as to completely cover the state. Geological phenomena to be seen along each tour are described. There are 108 illustrations, mostly photographs. All the photographs are excellent. Good maps of several of the areas discussed are provided, but this reviewer made considerable use of a large scale map showing the whole state. Such a map, marked so as to supplement the text and folded into a pocket in the rear cover, would have been a decided asset to the book. A glossary with 100 terms and a bibliography with 76 entries are compiled.

Three errors of fact were noted: (1) The lowest point in the continental United States is not—296 feet in elevation with respect to sea level as stated in four places in the book, but is—280 feet as stated on page 1; (2) The San Gabriel Range is *lower* than the San Bernadino Range (page 229); (3) Bumpas' Hell and Chaos Crags lie at the foot of *Mt. Lassen*, not Mt. Shasta (page 321).

The book is quite wordy and often objectionably repetitious. However, a vast store of technical information has been presented in non-technical style. The book should be of exceeding interest to those who enjoy understanding the out of doors, especially those who have had the opportunity to travel in California. It will be of great value to those unfortunates who are still merely planning such travel.—*E. F. Paddock.*

Adventures in Scenery, by Daniel E. Willard. The Jaques Cattell Press, Lancaster, Pa., 1942, 438 pp. $3.75.

Chemistry of Insecticides and Fungicides

Because of rapid progress in the chemical control of insects, it is important to keep abreast of new developments as well as to have a grasp of previous work on the subject. Since such information is usually found in widely scattered publications it is always a great help to fellow workers in a field to have such information assembled into one volume. The author of the book does this in an authoritative manner, because he has taught a graduate course on the subject for several years and the volume is an outgrowth of his notes used in that course. It is the most up-to-date book on the subject and is exceptionally complete in details on the various topics.

The contents by chapters are as follows: Introduction; The Arsenicals; Lead Arsenate; Fluorine Compounds and Miscellaneous Stomach Poisons; Nicotine and Pyrethrum; Rotenone and Miscellaneous Contact Poisons; Sulfur and Inorganic Sulfur Compounds; Oils, Fumigants; Copper Compounds; Mercury Compounds and Miscellaneous Fungicides; Wetting, Spreading, and Emulsifying Agents; Spray Residue Removal; Macro Methods; Micro Methods.

Except for the chapters dealing with macro and micro analytical procedures, the discussions of each chemical compound or group of chemicals is in regard to its sources, toxicity, manufacture, reactions with other insecticide and fungicide mixtures, action to plants and possible corrective measures. A selected list of references is included at the end of each chapter. A subject and author index are appended.

The book is a very worthwhile contribution and wide acceptance appears assured, not only by entomologists and plant pathologists, but also by horticulturists, and teachers and research workers in closely allied fields of science.—*Ralph H. Davidson.*

Chemistry of Insecticides and Fungicides, by Donald E. H. Frear. 300 pages. D. Van Nostrand Company. New York, 1942. $4.00.

THE GIPSY AT THE CRUCIFIXION OF CHRIST[1]

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Not so long ago, I came across the scenario of a 13th Century cyclical Passion Play, in Greek, from the Island of Cyprus (1). It is the earliest known attempt at a complete cyclical dramatization of the events of Holy Week. Starting with The Awakening of Lazarus, it embraces all the stations of the Passion, Crucifixion, and Resurrection of Jesus Christ, and concludes with the Lord's Injunction to His Apostles.

In general, this *Cyprus Passion Cycle* follows closely either the Greek New Testament, or the apocryphal Gospel of Nicodemus, and only in a few exceptional instances the homilies and similar authoritative sources. In other words, it represents throughout the accepted traditions of the Greek Orthodox Church of the period.

In view of such faithful adherence to the sacred traditions of the Church, one is perplexed by two stage directions in the scene that dramatizes Christ's Crucifixion and the Deposition from the Cross. The first of these acting directions reads: "And when they come to the place, the Smith shall appear and shall crucify Him, and the two thieves, one on the right hand, and the other on the left." The second reads, as follows: "And instantly the Smith shall come, and the Deposition from the Cross shall take place."

The two passages quoted do not employ the same Greek term for "Smith"; in the latter passage, "smith" corresponds to the classical Attic *chalkeus*, while in the former, it is a rendition of the Neo-Hellenic *komodromos*. Whereas the ancient word *chalkeus* is derived from *chalkos*, meaning, successively, "copper," "bronze," and "metal" (particularly, "iron"), the more recent term, *komodromos*, has no primary meaning connected with metal-working; basically, *komodromos* means "one who runs about the village." The famous 17th century Greek lexicon of DuCange (2) lists two meanings: "vagabond," and "itinerant metal-worker." In a footnote to his edition of the Scenario of the *Cyprus Passion Cycle*, the Byzantinist, Albert Vogt, of Geneva (Switzerland), remarks about this *komodromos: En réalité, ce personnage est un bohémien* ("In reality, this character is a Gipsy") (3). Unfortunately, Vogt fails to substantiate this interesting statement.

Until this day, the vagabonding metal-workers, especially the nail-smiths, in the Near East, as well as in the Balkans and the Greek Islands, including Crete, Cyprus and Rhodes, have been Gipsies; and, as the chronology of the Gipsy migrations shows, it is fully justifiable to assume the presence of Gipsy smiths on the Island of Cyprus, in the 13th Century, when the Passion Cycle originated.

Conclusive studies of the migrations of the European Gipsies were published, between 1872 and 1880, by the late Franz von Miklosich, of Vienna (4). He based his research on the fundamental discoveries about the provenience and structure of the Gipsy language, published, in 1844, by the German philologist, A. F. Pott (5). Miklosich analyzed the vocabulary of the Gipsy groups in the different countries of Europe and thus traced the migrations of these tribal units from the East to the West. He showed that all the Gipsies in the world share a common stock of basic words from some Hindi dialect, augmented by a considerable number of Persian words. Hence he drew the inference that their homeland was India—the particular basic dialect points to the Hindukush Mountains—and that from here they first turned to Persia. The presence of a vast amount of

[1]Read before the Anthropology Section at the 1942 meeting of the Ohio Academy of Science.

Greek roots in the dialects of all the Gipsy groups of Europe, and the absence of such Greek elements from the Gipsy dialects in Palestine, Egypt and North Africa, indicates that, after leaving Persia, the Gipsy people continued its migration in two columns: one following a southerly course toward Syria and Africa; and the other turning into Asia Minor and subsequently, with the Ægean Islands as stepping-stones, into the Greek mainland, in particular, the Peloponnesus. There is ample documentary evidence that they must have been living in Greece for about two hundred years when, from about 1400 A. D. onward, they began to appear in ever increasing numbers in Hungary, Bohemia, Germany, and all the rest of Europe, including the British Isles.

Although the chronology of their migrations preceding their arrival on the Greek mainland, about 1200 A. D., has not yet been clearly established, surely the afore-mentioned split into a west-bound and a south-bound column must have occurred at least another two centuries previously. Regardless of whether the Gipsies of Cyprus had branched off from the west-bound or the south-bound column, it is certain that, in the 13th Century, they must have been at home on the island for a long time. Since, moreover, the making of nails and other small iron-ware is an occupation common to both columns, the *komodromos* of the *Cyprus Passion Cycle* may be safely claimed as "a Gipsy nail-smith."

Indirectly, this inference is further substantiated by a Greek folk-tale and by several of its Slavic variants. In this popular legend, which I will discuss later, a Gipsy nail-smith figures at the Crucifixion of Christ.

Naturally, the questions arise: How did it happen that a Gipsy nail-smith could have ever become connected with this most sacred event which, moreover, was attested, in all its phases, by all four canonical gospels? And how may we account for the fact that the clerical author of the *Cyprus Passion Cycle* introduced this questionable character into his play as a perfect matter of fact; into that play which otherwise so strictly follows the Orthodox tradition? Indeed, not only once but twice does this character appear; for the smith who takes the Lord's body off the Cross, is doubtless meant to be the same fellow.

Medieval Greek literature offered not the faintest clue toward the solution of the mystery; the one Greek folk-legend with its Slavic variants helped to deepen rather than solve it. At the point of giving up, it occurred to me that iconography might provide a hint. In quest of this Gipsy Smith, I turned to Byzantine pictures of both the Crucifixion and the Deposition. The former yielded nothing; but all those of the Deposition showed a man in a short tunic who, with a pair of large pincers, extracted the nails that pierced the Lord's hands and feet.

All these pictures of the Deposition can be traced back to a pre-Byzantine prototype best represented by the miniatures of the so-called Rossano manuscript of the Greek gospels (6). The Byzantine type based on it represents the canonical tradition of the Orthodox Church, for it is this type that is described in the *Byzantine Guide to Painting*, a well-known compendium of rules for ecclesiastical artists (7).

With this in view, it was all the more perplexing to discover that the situation shown in this compositional pattern of the Deposition (Fig. 1) in no way illustrates any of the four canonical gospel accounts of this event, but that it depicts the incident such as told with much elaborate detail in an early medieval Greek legendary Life of Christ which, in turn, is based on the fanciful account of the apocryphal *Gospel of Nicodemus* (8). According to these non-canonical records, it was Nicodemus who, together with Joseph of Arimathaea, took down the Lord's body from the Cross; and it is minutely described, how they climbed up two ladders to the arms of the Cross, and how Nicodemus pulled out the big iron nails.

In a very few of the numerous cases where this elaborate and unbiblical pattern of composition was used in mural frescoes, we find the name of "Nicodemus"

inscribed near the nail-extracting figure; the *Byzantine Guide to Painting* also expressly states that it is Nicodemus who extracts the nails. The manner, however, in which the nail-extracting man is generally represented in the pictures of that pattern, was more likely to obscure, than to stress, his identity as Nicodemus: in the vast majority of pictures, he wears a short tunic and has bare legs and feet, while all the other sacred personages in the picture wear long tunics draped with cloaks; this applies equally to murals and to miniatures of gospel books. In the miniatures, moreover, the name of "Nicodemus" is never found ascribed, and it occurs in only a very few of the murals. Not a single miniature is known in which the nail-extracting man possesses a halo, while there is only the one or the other mural in which he is nimbed. In the majority of pictures this man is also much smaller of stature than the other sacred persons. How then could the people be expected to know that this swarthy little fellow was intended to be Nicodemus and not just what he looked like: a lowly *komodromos*, a Gipsy nail-smith, the kind that were roaming about the country-side making and peddling nails and metal-ware?

Fig. 1

Miniature from Byzantine Gospel Manuscript, 11th Century (*Paris, Bibl. Nationale, gr. 74,* fol. 208v). From H. A. Omont, *Evangiles avec Miniatures Byzantines de l'XIe Siècle* (Paris, 1908), p. 181.

Whenever in church any of the four gospel accounts of the Deposition was recited, was there ever a word said about Nicodemus' taking the Lord off the Cross, let alone, extracting the nails with pincers? Not even the clerics, when reading these accounts in their gospel books, could be expected to identify as Nicodemus the little nail-extracting figure of the miniature which, most inconsistently, accompanied each of the gospel accounts (9) but in no way fitted any of the four versions. Besides, there is another factor contributing to the belief that this figure was nothing but a common Gipsy smith: very frequently, the miniatures of this compositional pattern show, on their right side, Joseph and Nicodemus carrying the body of Christ to the grave (Fig. 1); in this half of the pictures, both figures invariably are equally tall, both have haloes and wear the long tunic with the himation; and since this part of the illustration actually fits the gospel account in which both Nicodemus and Joseph are mentioned by name (10), there could be no doubt in Nicodemus' identity, while the little nail-extracting fellow, over on the left, was all the more certain to be taken for just a common Gipsy nail-smith.

For the anthropologist, it is of especial interest to observe that the very existence of this notion presupposes a thorough familiarity on the part of the people with the Gipsies as the makers of nails and other ironware. It was so much a

matter of course to buy whatever nails were needed from the vagabond Gipsy smiths, that the people could not see how this ever could have been different; and since they had no feeling for anachronisms either, they naturally believed that the nails for the Crucifixion of Christ could not have come from anyone but a Gipsy. Weren't there in the very gospel book the pictures of the Gipsy pulling the nails, and was it not just as likely that this same Gipsy nail-smith also had hammered them in?

I have mentioned the Greek folk-legend about the Gipsy nail-smith at the Crucifixion of Christ. It was found on the Ægean island of Lesbos and also occurs in a few Slavic variants. As was the case among the Greeks, the basic notion was doubtless spread among the Slavic peoples by the pictures of the Deposition which, in the Slavic gospel books are essentially the same as those in the Greek gospels. They show exactly the same swarthy little nail-extracting fellow in the short tunic and with the bare legs.

Now as to the legend itself, in the Greek story, from Lesbos (11), the Virgin Mary meets the nail-smith, a Gipsy, and asks him whether he had seen her son. He replies that he was going to make five nails, instead of four, toward her son's impending crucifixion. Whereupon she curses him to be homeless forever.

Two variants, almost identical with each other as well as with the Lesbos version, are somewhat more explicit about that fifth nail; one is from Bulgaria (12), the other, from Bessarabia (13). In these stories, the Gipsy says that he has induced the Jews to drive the fifth nail into Christ's side [*Bulgaria:* . . . into Christ's heart]. Accordingly, the punishment is more clearly defined than in the Lesbos version: the Virgin curses the Gipsy to be black, enslaved, to be a smith, and to be despised by all [*Bulgaria:* . . . never to get anything to eat unless he begs for alms].

The Little Russians of Galicia have the following version (14): When Christ was crucified, the Gipsy nail-smith brought four nails and said that all of them were likely to be useful. However, only three were used; but Christ cursed the Gipsy that he should stray as useless as that fourth nail.

Another legend of Little Russia, from Galicia (15), tells this story: The Jews themselves dared not nail Christ to the Cross but commissioned a Gipsy to hammer in five nails. The Gipsy, however, drove in only four and swore that this was the number he had been hired for. Thenceforth, the Gipsies have been privileged by God to swear false at the fairs.

All these stories clearly express the people's contempt for the Gipsies. However, there is another set of versions that are favorable to the Gipsy in that they modify the basic motif: far from providing the nails for the Crucifixion, let alone, making them more than necessary, the Gipsy, now, steals one nail and, instead of being cursed, is being blessed, by Christ.

As the Gipsies strayed farther and farther away from the Greek domain into the Slavic Balkan countries and beyond, they appear to have learned how to take the sting out of this legend so persistently harmful to their reputation, by twisting it in their favor and peddling it themselves. A feeble attempt in this direction may perhaps be seen in the last-told of the two Little Russian variants, the tone of which is decidedly conciliatory.

I do not doubt, for instance, that the Gipsies had a hand in spreading among the Little Russians of Galicia, a story (16) in which the Carpenter (*not being* a Gipsy) is cursed never to become rich because he has made Christ's Cross, but the blacksmith (*being* a Gipsy) is blessed because he stole one of the nails.

Obvious pro-Gipsy propaganda may be seen in the following story from Lusatia (17), an East-German region inhabited by Slavic Wends: The Gipsy is blessed by Christ because he steals one of the four nails, so that Christ may be crucified with only three, thus sparing Him the disgrace of hanging on the Cross with His legs parted.

I want to conclude with two stories that were collected in a Gipsy camp in Alsace (18); sure proof that this type of the legend is actually peddled by the Gipsies themselves. Here is one of them: When Christ was about to be crucified, a Gipsy woman who was walking past, stole one of the four nails, so that Christ was crucified with only three. Therefore, the Gipsies are privileged to steal once in seven years.

This is the other story: When Jesus was about to be crucified, there were in the crowd two Jewish brothers, called Schmul and Rom-Schmul. Schmul showed a cruel satisfaction at the impending suffering of the Lord, but Rom-Schmul would have loved to save Christ from His terrible doom. That being, of course, impossible, he at least wished to show his good will; so he stole one of the four nails, and Jesus was crucified with only three. Later Rom-Schmul became a Christian, while his brother remained a Jew. It is this Rom-Schmul who became the ancestor of the Roms, as the Gipsies call themselves in their own language.

NOTES AND LITERATURE

(1) **Vogt, A.** *'Études sur le Théâtre Byzantin'*, in *Byzantion*, VI (1931), p. 49–63.
I have recently completed a reconstruction from this scenario of the entire *Cyprus Passion Cycle* in the original Greek. It is ready for the printer, together with an English translation, notes, and a detailed discussion of its literary character and history.

(2) **DuCange, C. Dufrense, Sieur.** *Glossarium ad Scriptores Mediae et Infimae Graecitatis* (Bratislava, 1891; re-impression of the edition of 1699).

(3) **Vogt, A.** *op. cit.*, p. 72, note 2.

(4) **Miklosich, F. von.** *Ueber die Mundarten und die Wanderungen der Zigeuner Europas*, in *Denkschriften der kaiserlichen Akademie der Wissenschaften, Philosophisch-Historische Klasse* (Wien, 1872–1880). See also Hopf, K., *Die Einwanderung der Zigeuner in Europa* (Gotha, 1870).

(5) **Pott, A. F.** *Die Zigeuner in Europa und Asien*, 2 Vols. (Halle, 1844).

(6) **Smith, E. B.** *Early Christian Iconography*, etc. (Princeton University Press, 1918), p. 183.

(7) There exist numerous manuscript versions of this work which has been in use—basically unchanged but modified in detail—in the painters' workshops of the Greek Orthodox Church throughout the greater part of the Christian era. One of them is printed, in translation, in Didron, A. N., *Christian Iconography*, etc. (English edition by J. Millington and M. Stokes), 2 Vols. (London, 1907), II, pp. 312–321.

(8) See **Donehoo, J. D.,** *The Apocryphal and Legendary Life of Christ*, etc. (New York, 1903), p. 366. For the apocryphal Gospel of Nicodemus, see *Evangelia Apocrypha*, ed. C. Tischendorf, 2nd edition (*Leipzig*, 1876).

(9) *Mark* XV: 46–47; *Matt.* XXVII: 59–61; *Luke* XXIII: 53; *John* XIX: 38–42.

(10) *John* XIX: 39–40.

(11) See **Dähnhardt, O.,** *Natursagen*, 2 Vols. (Leipzig, 1907), II, p. 294, from Georgeakis & Pineau, *Folklore de Lesbos*, p. 273.

(12) *ibid.;* II, p. 216. See also Rappoport, A. S., *Medieval Legends of Christ* (London, 1934), p. 232.

(13) *ibid.;* II, p. 217; from *Jubilejyni Sbornik v cest Millera*, etc. (ed. W. A. Jancuka), p. 95.

(14) *ibid.;* II, p. 216 f.; from Hnatjuk, *Galicko-ruski narodni legendi* (= *Etnograficnij Zbirnyk*, XII and XIII).

(15) *ibid.;* II, p. 217; see also Polivka, *Archiv für slavische Philologie*, XIX, p. 263.

(16) *ibid.;* from Hnatjuk, *op. cit.*

(17) *ibid.;* from Schulenberg, W. von, *Wendische Volkssagen and Gebräuche* (Leipzig, 1880), p. 47 f.

(18) *ibid.;* II, p. 293 f.; see also *Gipsy Lore Journal*, I (1889), p. 253.

THE ANTS OF ASHTABULA COUNTY, OHIO (HYMENOPTERA, FORMICIDAE)

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This list of ants collected in Ashtabula county and vicinity was compiled with two purposes in mind. First, to give some aid in determining the number of species of ants found in Ohio. Second, to record any interesting observations on ant behavior and ecological factors determining their distribution.

Collections were made for the most part during the spring, summer and late fall of 1938. A few collections were made during the fall months of 1937 and the spring of 1939. A record of each nest was made as to its location, habitat, general structure and environment, the date taken and interesting occurrences in the nest. The types of ants collected; whether they were workers, winged forms, queens, pupae, etc., were noted. The ants collected were placed in one dram vials with seventy per cent alcohol acting as a preservative.

DESCRIPTION OF THE REGION

The collecting area has been separated into three regions that seem to be distinct as to soil features and general topography. First, a lake plain strip about five miles in width south of the present shore of Lake Erie. Two parallel sand ridges mark the ancient beach lines at former lake levels—North Ridge and South Ridge. The soil of this region is mostly sand, with some gravel and sandy loam. Second, the gulf and ravines of the Grand River along the western side of the county; also a small part of Geauga county bordering Ashtabula on the west. This second region is all well drained and has a clay soil. The third area is south of the lake plain region, where the land is poorly drained and the topography is flat, rolling ground. This section has an impervious shale base with heavy clays from the glacial drift. (Read, '73).

The forests in these areas differ. In the lake plain region the forests east of Ashtabula city contain considerable hemlock with Beech-Sugar Maple-Tulip subtype occurring. (Hicks, '34). Toward the western side of the lake plain section are found Beech-Maple forests with scatterings of white elm, oaks, common locusts and hemlock.

The better drained section along the ravines of the Grand River is an Oak-Hickory association with scatterings of sugar maple, beech, white ash, tulip, hop hornbeam, wild cherry, and trembling aspen. Hemlock is found along the sides and bottoms of the ravines. The forests of the Geauga area are Oak-Hickory with sugar maple, beech, white ash, and white elm.

In the poorly drained section south of the lake plain region are found sugar maple, beech, white elm, walnut, tulip swamp white oak, some linden and trembling aspen.

ECOLOGICAL FACTORS

Dr. Shelford states: "Since the environment is a complex of many factors, every animal, while in its normal environmental complex, lives surrounded by and responds to a complex of factors in its normal activity." (Shelford, '13). Thus it is

[1]The author wishes to express his indebtness to Dr. C. H. Kennedy for all his help and advice in this work. Also for the use of his library which made reference study possible. The necessary laboratory work was done at the Franz Theodore Stone Laboratory, Gibralter Island, Put-in-Bay, Ohio. Myrmicas were identified by N. A. Weber.

impossible to study any group of organisms without taking into consideration their environmental surroundings.

Certain species of ants establish their nests where the sun can shine directly on them. Such species as *F. pallide-fulva* varieties, *F. fusca* var. *subsericea*, *F. sanguinea* varieties, *Lasius niger* var. *neoniger*, *F. exsectoides* and *Crematogaster lineolata* are found in fields and the borders of woods or open sunny places in woods.

Other ants are constantly associated with woods. In this region there can be distinguished no ants limited to a particular type of forest, the same species being found in oak-hickory or beech-maple climax woods. There are fewer ants not only in numbers but also species in a predominately hemlock area due possible to the covering of the ground with hemlock needles.

For log inhabiting ants the amount of deterioration of the logs determines what species are established in them. *Ponora coarctata pennsylvanica*, *Proceratium silaceum*, *Stigmatomma pallipes*, *Lasius claviger*, *Lasius umbratus*, *mixtus* var. *aphidicola*, and *Camponotus herculeanus ferrugineus* are found in logs rotted inside to a substance that can be dug out with the hand. This material is damp and fine enough so that the actual nest and galleries are often destroyed before the ants are seen. It is noted that ants do not occur in beech logs with stringy fibers. Wood inhabiting ants are seldom if ever found in logs that are moldy throughout.

The following species: *Camponotus herculeanus pennsylvanicus*, *Aphaenogaster tennesseensis* and *Creamtogaster lineolata* require solid logs or tree trunks with less moisture.

Small ants such as the *Leptothorax* genus are found in the cracks and crevices of the bark of solid logs. *Leptothorax acervorum* subs. *canadensis* spread their nests over two or three feet of solid maple bark located in sunny openings of the woods. The species *Leptothorax fortinodis* also nest in fallen maple trees with firm bark found in sunny places in woods; but restrict their nests to small areas two or three inches in diameter.

The mound building ants, *F. exsectoides*, nest principally in clay soils. These ants were plentiful south of the lake plain in clay, but only three nests were collected in sandy regions. These nests in the sandy areas were low flat mounds, while in the clay soils the nests grew quite large and cone shaped. The *F. fusca* var. *subsericea* mounds were plentiful in clay, being larger and more substantial than those of sandy regions.

Slave making species of the *F. sanguinea* group can live only in the vicinity of their slaves, which in this region are *F. fusca* var. *subsericea*. Similarly *Harpagoxenus americanus* is found only where *Leptothorax longispinosus* or *curvispinosus* are abundant.

The great adaptability of ants to food conditions makes it difficult to say that certain types of ground flora are required.

Geographically speaking the area seems to be too far east for *Formica ulkei* and it has not been collected. Just what the limiting factors are can not be stated. *Leptothorax acervorum* supsp. *canadensis*, a northern ant, seems to reach its southern limit in this region having been collected along the lake plain area.

FAMILY FORMICIDAE

Subfamily PONERINAE

Genus **Stigmatomma** Roger

Stigmatomma pallipes (Haldeman).

Typhlopone pallipes Haldeman. 1844. Proc. Acad. Nat. Sc. Phila. 2: 54. Worker.

Three workers were collected. Two were found under rocks in damp clay soil located in Beech-Maple woods. The rocks extended from three to five inches under the surface of the ground where it was always dark and damp. A third worker was found in a wet maple log whose

rotted material could be combed through the fingers. This ant is a rare and primitive species which is subterranean in its habits.[2]

Genus **Proceratium** Roger

Proceratium silaceum Roger.

Proceratium silaceum, Roger. 1863. Die neu aufgeführten Gattungen und Arten meines Formiciden-Verzeichnisses. Berl. Ent. Zeitschr. 7: 131–172. Worker.

This primitive ant is as rare as the preceding species, one worker only having been taken. The specimen was found wandering along a large white oak log that had rotted inside to a very damp punk. The log lay in a moist Beech-Maple woods. Locality, Thompson, (Geauga Co.).

Genus **Ponera** Latreille

Ponera coarctata Latr. subsp. **pennsylvanica** Buckley.

Ponera pennsylvanica Buckley. 1866. Descriptions of new species of North American Formicidae. Proc. Ent. Soc. Philad. 6: 171. Worker.

A much more abundant species than the two previously described. Nests were found in rotting stumps or logs, under stones, and in acorns lying in moist places. Workers, larvae, pupae, winged forms and nest queens have been taken. Males and females were collected from the fifteenth of August to the eighth of October.

All the nests were small, some with irregular and apparently unfinished galleries. This ant moves slowly and does not rush out in the face of danger to retrieve the brood as would one of the *F. pallide-fulva* group. (Wheeler, '10, Ants, p. 238).

Subfamily Myrmicinae

Genus **Myrmecina** Curtis

Myrmecina graminicola subsp. **americana** Emery.

Myrmecina latreillei subsp. *americana* Emery. 1895. Beiträge zur Kenntniss der nordamerikanischen Ameisen fauna. Zool. Jahrb. Syst. 8: 271. Worker.

One nest of this rare ant was collected from an acorn in a dense camp Beech-Maple climax forest. The ground had no vegetation other than moss. From this nest workers, pupae, one male and nest queen were taken.

Genus **Monomorium** Mayr

Monomorium Pharaonis (Linne).

Formica pharaonis Linne. 1758. Syst. Nat. Ed. 10: 580.

This tiny yellow ant has been transported all over the world by means of ships. Workers were taken from an apartment house in Cleveland, Ohio. They were found from basement to top floor raiding kitchens and bath rooms. Two lines would be formed, ingoing and outgoing, traveling in single file. They would be found in the butter, meats (bacon particularly), soaps, cold creams, etc.

It was wrongly thought by Linnaeus that the Egyptians were plagued by ants as well as other insects during Biblical times. Thus he gave them the name "Pharoah's Ants." They are believed to have originated in India.

Genus **Solenopsis** Westwood

Solenopsis molesta (Say).

Myrmica molesta Say. 1836. Descriptions of new species of North American Hymenoptera and observations on some already described. Bost. Journ. Nat. Hist. 1: 293. Worker.

Nests are found in open grassy places, under logs, stones or bark of trees. The species frequently nests with other ants such as the *Formica fusca* group, the *F. pallide-fulva* group, *Tapinoma sessile*, *F. exsectoides*, *Myrmicas* or *Aphaenogasters* that are in mounds or in the ground.

[2]Unless otherwise stated each ant mentioned in this paper has been collected in Ashtabula County.

Living up to its name, the thief ant, it can be very annoying in the kitchen at times. Males and females were found from the fifteenth of July through August.

Genus **Crematogaster** Lund

Crematogaster lineolata (Say).

Myrmica lineolata Say. 1836. Descriptions of new species of North American Hymenoptera and observations on some already described. Bost. Journ. Nat. Hist. 1: 290. Worker, female, male.

The colonies are found in fields and open woods nesting in rotting but fairly solid stumps, or logs, under bark and stones or in old abandoned *F. fusca subsericea* mounds. There is a wide range and much variation in types of localities of nests. Some are in damp places, but most are in fairly dry habitats. If one jars a stump these ants will boil up out of cracks and crevices. In general the colonies are large. Males and females are present from early August to late September.

Crematogaster lineolata var. **cerasi** (Fitch).

Myrmica cerasi, Fitch. 1854. Trans. N. York State Agric. Soc. 14: 835. Worker.

This variety has the same general form as the previously described *Crematogaster*, but is lighter in color, the thorax having more red on it. It is difficult to distinguish between the varieties. Nest locations have the same environment as *Crematogaster lineolata*.

Genus **Aphaenogaster** Mayr

Aphaenogaster fulva Roger.

Aphaenogaster fulva Roger. 1863. Die neu aufgeführten Gattungen und Arten meines Formiciden-Verzeichnisses. Berl. Ent. Zeitschr. 7: 190. Worker.

Nests are in damp woods, under stones, in rotting wood, often under clumps of leaves in a careless fashion. The soil is generally a clay with some sand. Males and females were found from the fifteenth of July to the twenty-fifth of September.

Aphaenogaster fulva Roger subsp. **aquia** (Buckley).

Myrmica (Monomorium) *aquia* Buckley. 1867. Descriptions of new species of North American Formicidae. Proc. Ent. Soc. Philad. 6: 341. Worker, female.

This reddish brown ant differs in habitat from *Aphaenogaster fulva* in being found in more open places; in fields, by roadsides and openings in woods. Nests are found under stones, in logs, under grass and dead vegetation. The soil may be clay or sandy loam.

Aphaenogaster fulva subsp. **aquia** var. **picea** (Emery).

Stenamma (A.) *fulvum* subsp. *aquia* var. *piceum* Emery. 1895. Beiträge sur der Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 8: 305. Worker, female, male.

This ant has the same general outlines of the subspecies *aquia* but has a pitchy black color. It may be confused sometimes with *Aphaenogaster fulva*. The nesting sites are the same as those of the species *fulva*.

Aphaenogaster tennesseensis (Mayr.).

Atta tennesseensis Mayr. 1862. Verh. Zool.-bot. Ges Wien. 12:743. Worker.

An ant with a cherry red color when seen in the field. It has epinotal spines longer than any other local *Aphaenogaster*. The typical nesting sites of this ant are found to be off the ground high up in stumps or in the top portion of logs or dead limbs, that do not touch the ground. The nests are located in places where sunshine can get to them. Winged forms were taken July 30, 1939. Nesting habits indicate that *tennesseensis* is aboreal rather than terrestrial.

Genus **Myrmica** Latreille

Myrmica punctiventris Roger.

Myrmica punctiventris Roger. 1863. Berl Ent. Zeitschr. 7: 190. Worker.

The nests for the most part were located in moist shady woods, with moss growing on the

ground and sides of trees. Several nests were collected from acorns that were damp inside and had considerable amounts of debris in them.

Myrmica scabrinodis subsp. **lobicornis** var. **fracticornis** Emery.

Myrmica lovicornis Nyl. subsp. *fracticornis* Emery. 1894. Zool. Jahrb. Syst. 8: 313.

A nest of this variety was collected in an open sunny spot of a Beech-Maple woods. The soil was fairly dry, sandy, loam. Vegetation was grass, club moss, cinquefoil, green ash, hazel nut, bushes, maple and white oak trees. There was no mound, just an opening from which a gallery extended down eight inches.

Myrmica scabrinodis subsp. **schencki** var. **emeryana** Forel.

Myrmica schencki Emery subsp. *emeryana* Forel. 1914. Deutsche Ent. Zeitschr. P. 617.

Four nests of this ant were collected in widely separated areas of the county. They were found in open fields or in sunny spots at the edges of woods. The soil consisted of clay or shale, generally dry and hard. Vegetation was predominantly grass, cinquefoil and berry vines. Surface structure of the nests varied. In some, openings were scattered over small domes of earth, in others they were flat at the surface, or under logs and stones.

Myrmica sabuleti subsp. **americana** Weber.

Myrmica sabuleti Meinert subsp. *americana* Weber. 1939. Lloydia 2: 144–6.

Nests were found in open fields where the soil was dry clay and the vegetation was grass, cinquefoil and berry vines. One nest was found in sand. Openings could be traced down for about a foot below the surface.

Genus **Leptothorax** Mayr

Leptothorax acervorum subsp. **canadensis** Provancher.

Leptothorax canadensis Provancher. 1887. Addit. Faun. Canada Hym, p. 245. Worker, female, male.

One nest was collected north of Geneva, Ohio. It was under the bark of the trunk and part of a branch of a fallen sugar-maple tree located in an open glade in a Beech-Maple woods. When the bark was lifted off the ants were captured as they came to the surface from their galleries that ran lengthwise of the soild wood. Workers only were collected from this nest. The ant is a northern form as the name indicated. The nest collected is the only record so far for Ohio.

Leptothorax fortinodis Mayr.

Leptothorax fortinodis Mayr. 1886. Die Formiciden der Vereinigten Staaten von Nordamerika. Verh. Zool.-bot. Ges. Wien. 36: 451–452. Worker, female.

A single colony of this species was taken. It was found in the bark of a fallen maple tree located in an open sunny area of a dense Beech-Maple woods. The nest was small, not more than three inches in length. It is the exact opposite of the previous form which spreads out over a large area of a log. The collection was made July 28. Workers, pupae, nest queen and two males were taken.

Leptothorax longispinosus Roger.

Leptothorax longispinosus Roger. 1863. Die neu aufgeführten Gattungen und Arten meines Formiciden Verzeichnisses. Berl. Ent. Zeitschr. 7: 180. Worker.

The nests of this small dark ant are found under the bark of dead and living trees, in acorns, snail shells, in hollow twigs and oak galls. Quite often one or two may be seen by a collector without his being able to locate the nest.

Twenty-four acorn nests were collected in an area twenty by twenty-five feet, located along the top of a ravine cut by the Grand River. The acorns were one-half inch in diameter, having fallen from red oak trees. The outside covering of each was solid except for a tiny opening next to the ground. The acorn centers were hollow and dry, some being exceedingly clean while others contained a small amount of debris. Since collections were from mid-September to the middle of October practically all of the nest inhabitants were procured. It would seem that a semi-hibernating condition existed. The largest nest contained one hundred and ten workers and a nest queen. The average sized nests contained forty to fifty workers together with the nest

queen and pupae. The smallest nests contained four to seven workers; however, they contained *Harpagoxenus* queens which would indicate that a number of workers had been killed in a raid.

The choice of acorns for nests is correlated with the fact that colonies are generally small. Small colonies are due possibly to the relatively small fecundity of the female since she is but little larger than the worker. Then, too, there is usually not more than one fertile female to a nest according to the records of this region. Only one nest contained two normal queens together with one aberrant female.

Leptothorax curvispinosus Mayr.

Leptothorax curvispinosus Mayr. 1866. Myrmecolgische Beiträge. Sitz.-ber. Akad. Wiss. Wien. 53: 508, pl. f. 13. Worker.

This ant nests in hollow twigs, under bark of trees in acorns and oak galls. An occasional ant will be seen wandering about in the grass or on the twigs of bushes, To find the nest of such wanderers infinite patience is required.

Complete nests were taken from acorns lying on the ground. These acorn nests always had a good outside covering however thin they might be. The inside would be dry with small amounts of debris. The woods were open Beech-Maple with a scattering of red and white oak trees. The soil was dry clay with a shale base. The ground vegetation was mostly grape vine runners and some tufts of grass. Workers, nest queen, larvae, and pupae were collected.

Leptothorax curvispinosus subsp. **ambiguus** Emery.

Leptothorax curvispinosus subsp. *ambiguus* Emery. 1894. Beiträge zur Kenntniss der Nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 8: 317–320. Worker.

Ten nests were collected; four from soil at the edges of woods in open fields; six from acorns of red oaks scattered along the edges of Beech-Maple woods.

The ants from nests collected in open fields were light in color. The colonies were located in and among roots of cinquefoil (*Potentilla palustris*) and sheep sorrel (*Rumex acetosella*). The nest would spread out a foot in radius with galleries running underground from one group of roots to another; or around the roots of one plant. By carefully pulling up the cinquefoil the nests were encountered one or two inches under the surface of the ground. The soil was always dry, fairly hard clay. Nest locations were far enough out from tree trunks to get plenty of sunshine. The principal vegetation was cinquefoil, sheep sorrel, golden rod and plantain with oak trees along edge of woods. Workers, pupae and nest queens were collected.

Ants collected from acorns were of a darker hue. The acorns were one-half inch in diameter and were from red oak trees. The outside shell was in perfect condition with a small opening on the surface next to the ground. They were dry inside with little debris. There was some ground flora, grape vine runners and tufts of grass. These nests were located at the top of a ravine of the Grand River, at Harpersfield, Ohio.

Genus **Harpagoxenus** Forel

Harpagoxenus americanus (Emery).

Tomognathus americanus, Emery. 1895. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 8: 272. Worker.

A black ant recognized by the groove formed by the frontal carinae which extend back to the vertex, giving the antennal scapes a resting place.

This extremely rare ant enslaves species of *Leptothorax*. Three isolated queens were taken from small *L. longispinosus* in nests found in acorns. Another interesting nest was made up of both *L. longispinosus* and *L. curvispinosus* workers together with two *H. americanus* workers without a queen. An explanation of this unusual nest might be found in Dr. Creighton's article entitled "The slave raids of Harpagoxenus americanus." He explains an almost similar mixed colony found by Wheeler in this manner. "I would consider Dr. Wheeler's mixed *Leptothorax* colony as a remnant originally formed by dulosis from which the *Harpagoxenus* had migrated or been killed off while raiding."

About 50 acorn nests of various species of *Leptothorax* were collected along the top of a ravine of the Grand River at Harpersfield in an attempt to locate more, and complete, *Harpagoxenus americanus* nests; they are yet to be found.

Subfamily Dolichoderinae

Genus **Tapinoma** Förster

Tapinoma sessile (Say).

Formica sessilis Say. 1836. Descriptions of new species of North American Hymenoptera and observations on some already described. Bost. Journ. Nat. Hist. 1: 287–288. Worker, female.

A very common ant nesting under rocks, logs in old mounds of other ants, under bark of trees and clumps of dead leaves. The nests are in fields or open woods, where the sun can get to them. They often have an untidy appearance as if housekeeping had just started, nothing being in place. Pupae are often piled up in heaps or just under the bark of a log in a careless manner.

Subfamily Camponotinae

Genus **Prenolepis** Mayr

Brachymyrmex heeri subsp. **depilis** Emery.

Brachymyrmex heeri Forel subsp. *depilis* Emery. 1895. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 7: 635. Worker, female, male.

Nests are located under stones of open woods. The soil may be rather dry clay. Colonies are always small and do not go more than one or two inches down into the ground under the stones. Males and females make their appearance from the middle of August to late September.

Prenolepis imparis (Say).

Formica imparis Say. 1836. Descriptions of new species of North American hymenoptera, and observations on some already described. Bost. Journ. Nat. Hist. 1: 287. Female, male.

This interesting ant is found most readily in gardens, under grape arbors and fruit trees in sandy soil. They are the first ants to open their crater nests in the spring. At that time there will be a flight of males and females which have wintered over. During the hot summer months workers are not readily found but in the fall they open the nests again and are numerous on fallen fruit.

Prenolepis imparis imbibes fruit juices and secretions of flowers, loading their gasters until they are so distended that walking is difficult. Many workers winter over in this replete condition. In this respect they resemble the honey ants (*Myrmecocystus*) of southwestern United States and Mexico.

Genus **Camponotus** Mayr

Camponotus herculeanus subsp. **pennsylvanicus** (DeGeer).

Formica pennsylvanica DeGeer. 1773. Mem. Serv. Hist. Insect. 3: 603. Pl. 31, figs. 9, 10. Worker, female, male.

A large black ant commonly called the "carpenter ant." The nests are in dead logs, stumps or decayed centers of living trees, or in the wooden foundations of houses. Galleries are formed all through their abode.

When a nest is opened in which a young queen and her brood are found the queen will stand over the brood attempting to guard it. This would indicate to a high degree the instinct of protection. It is certainly the opposite of the case found in the *Ponerinae* subfamily where workers move away from the brood when disturbed.

This ant will make trails an inch in width from one tree to another. The workers have been observed to lie down on their side and take a "nap" while traveling these trails. When disturbed these ants will run along a slab or bark and drop over as if dead, completely relaxed; when the danger is passed they will scurry along to a safe hiding place.

When a nest has been built in the timbers of a house much damage may be done before the occupants are aware of the fact.

Camponotus herculeanus subsp. **pennsylvanicus** var. **ferrugineus** Fabr.

Formica Ferruginea (Fabricus J. Chr.). 1798. Suppl. Ent. Syst. p. 279. Worker, female.

The only nest taken was found in a very damp maple log; the rotting material so fine it could be sifted through the fingers. This log lay in a Beech-Maple woods that was quite damp. Only the queen and her first brood were collected.

Camponotus herculeanus subsp. **ligniperdus** var. **noveboracensis** (Fitch).

Formica noveboracensis Fitch. 1854. N. York State Agric. Soc. 14:52. Worker.

This ant is not as abundant as *C. herculeanus pennsylvanicus* but has the same nesting habits as the other. Workers, pupae, winged males and females were collected. The winged forms were taken July 30.

Camponotus caryae (Fitch).

Formica caryae Fitch. 1855. Trans. N. York State Agric. Soc. 14: 855–859. Worker, female, male.

A black ant separated from the larger *Camponotus* group by a notch in the middle of the anterior border of the clypeus.

This is not an abundant species and only a few workers have been collected as they wandered about on the stems of blackberry canes and beech shoots in open fields.

Genus **Lasius** Fabricius

Lasius niger var. **neoniger** Emery.

Lasius niger var. *neoniger* Emery. 1893. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 7: 639. Worker, female, male.

This ant and *Lasius niger americanus* are the only *Lasius* varieties that are not strictly hypogaeic. Workers are seen above ground in the foliage of trees attending aphids. *Lasius niger* var. *neoniger* has a preference for sandy soil in which habitat it replaces *L. niger* var. *americanus* in abundance. Occasionally it will nest in a log or stump but for the most part it is found in small crater shaped nests in sandy soil.

Lasius niger subsp. **alienus** var. **americanus** Emery.

Lasius niger alienus var. *americana* Emery. 1893. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 7: 639. Worker, female, male.

This is the most common ant in the region. Colonies are found nesting under stones, bark, in logs and stumps; they may be in ground that is damp or dry, in fields or woods, thus, showing great adaptability to the physical conditions which they encounter.

This ant is a pest in gardens and fields where it will place aphids on rose bushes, the roots of corn, etc. Winged forms were collected from late July to the middle of September.

Lasius flavus subsp. **nearcticus** Wheeler.

Lasius flavus var. *nearcticus* Wheeler. 1906. New ants from New England. Psyche. 13: 38–39.

One nest was collected and it did not conform to the usual nesting situation of other localities. Usually this ant is found in damp places under stones or leaf mold in well shaded woods. The nest collected was found under a flat stone eight by ten inches. The ground was hard, dry clay in an open Beech-Maple woods. There was no ground vegetation and the only trees were sugar-maples and white oaks. Workers and pupae were collected.

Lasius umbratus subsp. **mixtus** var. **aphidicola** (Walsh).

Formica aphidicola Walsh. 1862. On the genera of aphidae found in the United States. Proc. Ent. Soc. Philad. 1:310. Worker, male.

This ant is found nesting in the damp rotten wood of stumps or under rocks located in moist places. They most generally inhabit deep Beech-Maple woods; however, they will nest in a field if the moisture is sufficient. They are hypogaeic, attending white root aphids. Workers and one nest queen were collected.

Lasius (Acanthomyops) claviger Roger.

Formica clavigera Roger. 1862. Einige neue exotische Ameisen-Gattungen und Arten. Berl. Ent. Zeitschr. 6: 241–242; 1, fig. 13. Female.

Two nests of this species were collected, both nests being in stumps of trees that had rotted to a condition almost beyond recognition. This rotted punk was damp enough to be molded in the hands. The main portion of the nests was found in the center of stumps with Virginia creeper growing up through it. On the roots of this plant the ants had placed white aphids. A lemon verbena odor is given off by these ants.

Genus **Formica** Latreille

Formica sanguinea subsp. **subintegra** Emery.

Formica sanguinea subsp. *rubicunda* Emery var. *subintegra* Emery. 1893. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 7: 648, pl. 22, fig. 3. Worker, female.

This ant enslaved *F. fusca* var. *subsericae* by making forays to capture the young, thus making mixed colonies of the two species. The soil is generally clay with sand mixed in with it. Workers only were collected.

Formica sanguinea subsp. **subnuda** Emery.

Formica sanguinae subsp. *rubicunda* Emery var. *subnuda* Emery. 1895. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 8: 335. Worker.

The nests are located at the edge of woods in sunny places. There may be a "bed" of openings a foot or more in diameter, level with the ground. The soil is generally sandy clay. Grass is allowed to grow over the mounds. The nests are generally mixed with *F. fusca subsericea* which the sanguinea's raid and enslave.

Formica exsectoides Forel.

Formica exsectoides Forel. 1886. Espices nouvelles de Fourmis Americaines. Ann. Soc. Ent. Belg. 30 C. R. 38. Worker, female.

These mound builders have nests that may be three feet across and thirty to forty inches high. Some mounds in a more sandy soil are only nine inches to a foot in height but are much longer than the higher mounds. Openings into the nests are located along the side walls. The tops of the mounds are covered with debris of small sticks and vegetable matter. Grass grows on the mounds except at the summits. Mounds are built in sunny openings in woods or out in fields. The ants prefer a clay soil. Only three nests were located in the northern part of the county where the soil is more sandy and loose.

Workers from several colonies have been observed attending green aphids on the leaves of trees. The workers will attack when the mound is disturbed and are known to bite off the heads of other ants.

Formica fusca Linnaeus var. **subsericea** Say.

Formica subsericea Say. 1836. Descriptions of new species of North American hymenoptera, and observations on some already described. Bost. Journ. Nat. Hist. 1: 289. Worker, female.

A very common ant, building mounds in clay soil in open sunny places. It is not uncommon to find fifteen to a hundred mounds in a half acre field. They may grow to be two feet in height and three feet in diameter at the base. The openings into the mounds are mostly along the sides with some on the top. The tops of the mounds are generally flat. Vegetation is very abundant about the mounds. These ants also nest under stones or have any number of openings in a "bed," level with the ground.

The ants not only attend aphids but also eat dead insects. *F. fusca subsericea* is a timid ant, allowing other ants such as *Tapinoma sessile* and *Solenopsis molesta* to nest with it. It is raided by *F. sanguinea* varieties which capture some workers, but take pupae mostly.

Formica neogagates Emery.

Formica fusca subsp. *subpolita* Mayr var. *neogagates* Emery. 1893. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 7: 661. Worker, female, male.

Two workers of this species were found traveling along the ground at a rapid rate of speed. The soil was dry, hard clay in a planted white pine forest. These ants were dodging rapidly from one hiding place to another making them difficult to capture. The trees were far enough apart to allow sun to shine on the ground. Grass and poison ivy were the principle vegetation.

Formica pallide-fulva subsp. **nitidiventris** var. **fuscata** Emery.

Formica pallide-fulva subsp. *fuscata* Emery. 1893. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 7: 656. Worker, female.

One nest of this species was collected. It was found out in a cut hayfield under an eight inch square rock. There was one gallery which went down about a foot and then branched in all directions. The soil was a sandy clay that was very dry. The vegetation was blue grass.

Formica pallide-fulva subsp. **schaufussi** var. **incerta** Emery.

Formica pallide-fulva Latreille subsp. *schaufussi* var. *incerta* Emery. 1893. Beiträge zur Kenntniss der nordamerikanischen Ameisenfauna. Zool. Jahrb. Syst. 7: 655–656. Worker, female, male.

These ants nest in open fields and at the edge of woods, under stones, or in small craters which are difficult to see. The nest has a single opening from which a shaft goes down about a foot or more, than branches out in all directions to form chambers deep in the ground.

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LIFE HISTORY AND HABITS OF THE CICADA KILLER IN OHIO

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The Cicada Killing Wasp (*Sphecius speciosus* Drury[2]) has long been of interest to entomologists and of much popular interest to naturalists wherever it occurs. Riley (18) in 1893 published in "Insect Life" the first account of its life history and habits. Observations of the writers have revealed a number of inaccuracies in this report and omission of essential data. These errors and omissions have been repeated by subsequent writers on the subject, particularly Marlatt (12), and Smith (20). Certain of these inaccuracies have been corrected, (Davis 5), but as yet no complete account of the life history and habits of this insect has appeared. For this reason the writers are here attempting to bring together the essential facts concerning its life history and habits based on published accounts and their own observations.

Beginning with the summer of 1934, and continuing through 1940, we studied the habits of this wasp for a period of a week or more each year during the height of its activity. A large part of the data reported on were collected from a colony of these insects consisting of several hundred burrows on a 4-H Club Camp site in Eden Township, Licking County, Ohio. Many observations have been made, however, at other colonies in southern Ohio counties. In addition to our own observations those of other interested individuals have been reported to us.

DESCRIPTION AND DISTRIBUTION

Due to its large size, general distribution and interesting habits *Sphecius speciosus* has been described in many insect books and needs no further description here. Its habit of digging burrows and provisioning them with cicadas is the means by which it is usually recognized and has earned it the name of cicada killer, sand hornet or golden digger-wasp.

In Ohio, *Sphecius speciosus* is most abundant in the southern two-thirds of the state but records from as far north as Cleveland in Cuyahoga County and Van Wert in Van Wert County have been obtained. Colonies appear to be most numerous in the unglaciated Allegheny Plateau and to occur only locally elsewhere. Although complete records are not available it is quite probable that it occurs in all of the counties, south of the Lake Erie drainage. Twenty-five of the 27 counties for which records are available are in this area.

LIFE HISTORY

Emergence:

At Dayton, Ohio, during a three-year period (1937–1939), the average date for the emergence of adults from Sphecius larval cases stored over winter in well-drained soil was July 1. Specimens stored at room temperature emerged approximately one month earlier. The adults made a nearly perpendicular tunnel to the surface in completing their emergence.

It is interesting to note that the emergence date of Sphecius closely approximates that of its prey, as was indicated by the concurrent appearance of cicadas at Dayton, Ohio, in 1939 and 1940. As noted later, however, Sphecius does not begin to prey upon cicadas until several weeks after its emergence.

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[2]Order Hymenoptera, family Sphecidae, sub-family Bembicinae, tribe Nyssonini.

Feeding and Mating:

The activity of the cicada killer immediately after emergence is apparently not well known. Recent observations only substantiated those of other observers who report that during this period adults feed upon the exudations of various trees including willows, oaks, sycamores, and the flowers of compositae and other plants.

Mating activity occurs concurrently with feeding and may take place far from where burrows are later established, Davis (5). Marked specimens released at Dayton, Ohio, from June 25 to July 3, 1939, were not again observed for at least two weeks. Shortly after their reappearance the excavation of burrows was begun.

Mating has been observed to take place in the air by a number of observers, Davis (5), Denton (7), Manee (11), and the authors. Males perch on exposed vegetation and pursue females which come near. When mating does occur the pair often drop to the ground together but recover quickly. Females have been observed similarly to pursue members of their own sex which makes it difficult to determine if mating is actually taking place. J. W. Sites, however, in conversation, has reported observing a pair of cicada killers quietly copulating while resting on a tall weed in a field near Zanesville, Ohio, July 29, 1940. This pair was so quiet that he was able to capture them easily.

Sex Ratio:

Of 25 adults emerging from stored larval cases, 15 were males and 10 females. Seven specimens collected in Muskingum County were females and of the specimens at the Ohio State University and the Ohio State Museum 29 are males and 37 are females. Denton (7), records obtaining 13 females and 7 males from a group of 20 specimens he collected from a colony on August 2, 1930, at Robbinsville, North Carolina. These collections, totaling 128 specimens, indicate a sex ratio of 70 females to 48 males, or 59.3 per cent females to 40.7 per cent males. During the height of Sphecius activity, however, males are seldom observed.

Digging and provisioning of burrows begins in mid-July and reaches a peak of activity the first two weeks in August. A marked Sphecius released at Dayton on July 3, 1939, was observed cruising back and forth along a lawn terrace on July 17 and began excavating there on July 22. Usually by the first of August there is considerable digging and provisioning of burrows in Sphecius colonies. Although they have been observed to be abundant as early as July 4, at the Eden Township colony in Licking County, their burrows have not appeared in large numbers there until some weeks later.

Location and Description of Colonies:

With few exceptions cicada killer colonies are located in well-drained, light-textured soil, in full sunlight where vegetation is scant or absent. Included in the list of sites studied in Ohio are such locations as: tree seedling and lining out beds at the Marietta and Zanesville tree nurseries, greenhouse flat boxes at Zanesville, a cinder roadbed at Zanesville, tennis courts on the Ohio State University campus, a school yard at Rocky River, a new earth fill in a city yard at Dayton, a formal garden surrounded by a concrete platform at a railroad station at Cambridge, a tobacco field in Clermont County, and frequently in lawns, over-grazed pastures, and old fields in the southern part of the state.

Size of colonies studied varied from one of two burrows to one of 373. The latter colony is definitely known to be at least 9 years old and is probably much older. It occupies an area of approximately one acre of thin pasture. The area occupied is variable and does not seem to be limited by the number of burrows. The distance between burrows ranges from a little more than one foot to 15 feet or more. Burrows in the large colony studied were grouped in units where they averaged 6.9 per 100 square feet.

Digging of Burrows:

Digging of burrows begins before mating activity ceases in the colony and continues throughout the summer until late August. The cicada killer accomplishes excavation by using the mouth parts to dislodge soil and other particles and to cut through roots of plants. The material so removed is pushed under the wasp's body by the fore legs and after a small amount accumulates it is kicked out behind in much the manner employed by a dog. As digging progresses beyond

the point where this method is effective the soil is dragged to the surface by the forelegs or is pushed out with the head. The accumulated pile of soil outside the burrow is kept away from the opening and a neat U-shaped entrance to the burrow is maintained. (Fig. 1).

The burrow, when in readiness for the first cicada, is dug usually to a depth of 6 to 10 inches. It measures approximately one-half inch in diameter and from 12 to 18 inches in length from the entrance to its terminus where the first cell is excavated. The rate at which digging progresses probably varies with the soil condition. The rate of digging observed in a well-packed, clay fill at Dayton, Ohio, gives some indication of the cicada killer's digging ability. In this case a tunnel was dug out ready for the first cicada between 2 P. M., July 21, and sometime prior to 8 A. M. July 22. Approximately one-half pint of soil was removed during this period.

Cells in which cicadas are stored are broadly egg-shaped with the long axis in the horizontal plane and perpendicular to the tunnel. They measure approximately 2 inches deep, 1½ inches wide, and slightly over an inch high. The walls of the cells are smoothly shaped and no loose dirt is left on the cell floor. Shaping of the cell is probably accomplished with the same tools as used in excavating the burrows.

Generally, after a cell has been provisioned with a cicada or cicadas, and an egg laid on one of them, it is plugged with a thin wall of earth and a new cell made immediately in front of it. As many as four provisioned cells have been found in one such series. After a cell or series of cells is completely provisioned a new lateral off the main tunnel is excavated and the process repeated. The number of cells fitted per burrow varies considerably but was found to average 15.8.

Hunting and Provisioning Burrows:

The Cicada Killer, like other solitary wasps, Peckham (15), makes no effort to obtain its prey until a cell has been made ready for it. Attempts to alter this habit by placing a healthy cicada at or near the burrow entrance during the digging of the tunnel proved unsuccessful. Equally unsuccessful were attempts to entice Sphecius to attack cicadas tethered with a thread and permitted to fly about their colonies while they were actively working and flying around.

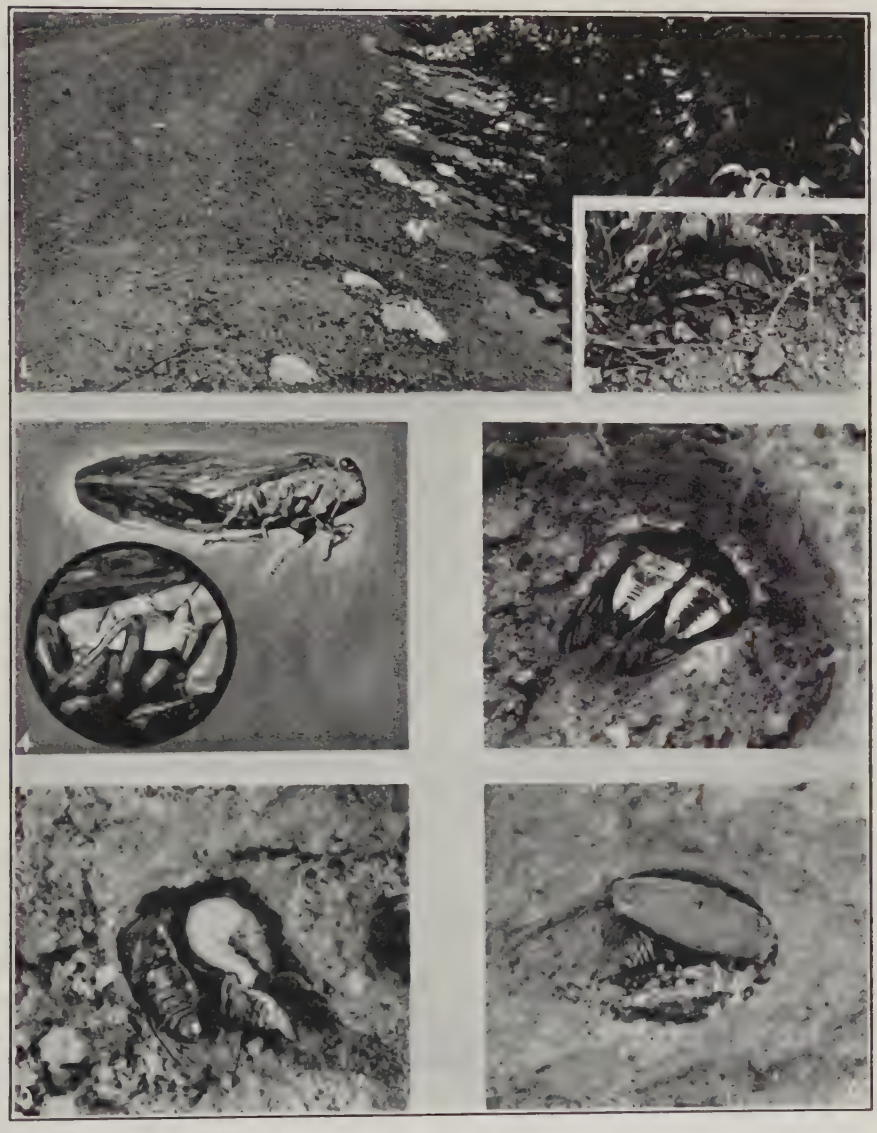
Sometimes before leaving the vicinity of its burrow a wasp would circle around it several times before departing in the direction from which it later returned with a captured cicada. Equally often, however, no preliminary maneuvers were engaged in, the Sphecius simply flying directly toward its hunting territory, or if windy, heading first into the wind and, after gaining a height of 10 to 15 feet, flying in the desired direction.

In hunting, the wasp approaches a tree or shrub and slowly circles closely about the trunk, gradually working its way up through the limbs and branches. It sometimes alights on the bark and continues the search on foot.

The method of attacking cicadas when located has been ably described by Mr. Conrad Roth of Portsmouth, Ohio, (in a letter of August 23, 1939) who witnessed a capture of *Tibicen pruinosa* at close range. "The wasp darted backward and forward in front of the cicada several times meanwhile bending the tip of the abdomen downward and forward. It then hit the cicada viciously and injected the sting between the abdominal segments. The cicada buzzed shrilly and immediately ceased struggling. The wasp managed to hold its prey to the limb of the tree and pulled it up on the top side of the limb. After this effort the wasp turned the cicada over on its back, straddled it, grasped the body firmly and flew off with the burden toward a Sphecius burrow."

In carrying its prey, Sphecius has always been observed to hold it firmly in an inverted position by locking its middle pair of legs about the neck between the eyes and the pronotum, (Fig. 2). Early writers, Riley (18), Smith (20), Marlatt (12), figured Sphecius dragging a cicada right side up. This error was corrected, however, by Davis (5).

Reports have been received indicating that a Sphecius sometimes takes its prey while in full flight. J. N. Knull, in conversation, reported one such capture which he witnessed at Cape Henry, New Jersey. In this instance the wasp hit the cicada while in flight and tumbled to the ground with it. Whether it stung its prey while in the air or after striking the ground was not observed. That this is not the usual method of attack, however, is evident from the apparent safety enjoyed by cicadas observed flying to and from trees 10 to 25 feet in height while cicada killers were busy searching the lower limbs in the usual methodical manner. It is quite likely,



1. A colony of burrows along a cinder roadway.
2. An adult female wasp with a captured cicada.
3. A male and female cicada (*Tibicen lyricen engel.*) stored in a cavity.
4. Egg of wasp on captured cicada.
5. Nearly full grown larva feeding on cicada.
6. Earthen case in which larva overwinters and completes life cycle.

however, that should a cicada attempt escape by flight after being located, pursuit and probably capture would result.

The captured cicada is carried in flight to the burrow entrance from distances sometimes in excess of 100 yards. Usually flight terminates at or within a few inches of the entrance and the cicada is then speedily carried down the tunnel. Less successful landings in grass or other vegetation frequently result in abandonment of the prey as the struggle to drag the burden to the burrow becomes too great. Davis (4), reported an observation by Morse of Sphecius dragging its prey up a maple tree and taking off from a high point after an unsuccessful struggle to reach its burrow through grass on the ground. Similar observations have been recorded by Davis (5), and Manee (11).

Cicadas are placed in the cells on their backs with their heads directed away from the open side (Fig. 3). When more than one cicada is placed in a cell they are laid side by side and all in the same direction. The number of cicadas stored per cell varies between 1 and 3 and averages 1.3.

Species of cicadas stored in burrows usually were those common in the vicinity of the colonies. Their relative abundance was about proportional to that noted from the number of males of each species heard in the immediate vicinity. Table I lists the species taken from colonies, by habitats, for which definite determinations have been made by W. T. Davis. In addition to these species, records of the following have been obtained: *Tibicen robinsoniana* taken from a cicada killer in Adams County, Ohio, August 11, 1935, by Conrad Roth and Edward S. Thomas; *T. marginalis* reported being carried by Sphecius up a telephone pole by Manee (11); and Sphecius hunting in willows in which *T. marginalis* were abundant, reported from Butler County in 1937 by E. E. Good. Davis (5), believed that *T. auletes* is taken also but no records have been found to substantiate his belief. Riley (8), reported the taking of *T. pruinosa* as has also Mr. Conrad Roth of Portsmouth, Ohio. Viereck (22) records it as preying on *T. dorsata*, *T. tibicen*, and *T. marginata* based on records by Ashmead.

Probably all of the cicadas with arboreal habits occurring within the range and active season of Sphecius are taken to some extent. *Okanaga rimosa* and the 17-year cicadas, *Magicicada septendecim* (Lin.), and *M. cassini* Fisher, and *Melampsalta calliope*, are too early in their appearance to be taken by Sphecius in Ohio. With the exception of possible stragglers their season is usually over two or more weeks before active hunting by Sphecius begins. Museum records of *Magicicada* in Ohio, for instance, range from May 26 to June 28.

The sex ratio of cicadas stored in burrows is greatly in favor of females. Of 703 Sphecius captured cicadas examined but 204 were males giving a sex ratio of 7 females to 3 males. Davis (5), noted this and in so doing called attention to the erroneous idea prevalent among naturalists that Sphecius secures its prey by hunting only singing males. The disproportionate sex ratio may be due to the greater susceptibility of females to the hunting system employed by the wasp. Male cicadas are probably more readily disturbed than are ovipositing females.

Laying of Eggs and Development of Larvae:

Only one egg is laid per cell irrespective of the number of cicadas it contains. Eggs are cylindrical or cigar shaped, transulcent, greenish-white in color and measure from 3 to 5 millimeters in length. The egg is placed lengthwise snugly under the femur of one of the middle pair of legs, (Fig. 4).

Eggs found on cicadas in the last completed cells in a number of burrows hatched within 24 to 36 hours. Presumably they were only a few hours old as wasps had been observed a short time previously to enter the burrows with cicadas. The newly-hatched larvae began feeding by inserting their mouthparts into the body cavity of the host at the base of a mesothoracic coxal plate. (Fig. 5). As the larva grew its feeding was transferred to the base of each of the remaining coxal plates until nothing remained of the cicada but a skeleton. When more than one cicada was available feeding was continued in the same manner on the second or third specimen.

Growth of the larvae is very rapid. One specimen which hatched prior to 8 A. M. August 29, 1939, had attained a length of 1.6 centimeters 48 hours later, and had completely eaten the body contents of the cicada on which it was feeding in 82 hours. At that time it measured 2.8 centimeters in length when quiet and 3.2 centimeters when extended in feeding. After feeding

briefly at the base of one coxal plate of another cicada it became restless and crawled around for several hours. By 8 A. M. September 2, 1939, 14 hours later, it had begun to spin a larval case consisting of a very open framework of thin fibres. By 5 P. M. of the same day a thin, silken-like, cylinder-shaped case had been woven which was open at both ends. The larva could easily be observed through this case as it seemingly shellacked the inner surface with a gelatinous substance applied by the mouth parts. The larva was observed virtually to crawl over itself in the cramped quarters of the larval case as it applied the finishing touches to the interior. After the open cylinder was apparently completed the ends were spun and sealed shut.

The completed larval case was broadly spindle shaped (Fig. 6), measuring 4.4 centimeters in length and about 1.5 centimeters in diameter. Both ends of larval cases are truncated with one noticeably larger than the other. Near the center of the cases a narrow band of outwardly opening pores occurs. The number of pores present in a series of 25 cases varied between 6 and 14 with an average of 10. The exact function of these pores is not known but presumably they represent some sort of respiratory or moisture regulating mechanism.

As the case hardens it becomes earthen-brown, stiff, and capable of withstanding reasonable handling. Soaking in water at room temperature for a half hour did not seem to weaken the cases nor to injure their occupants. Storage of the cases under very moist conditions for several months, however, made them soft, whereas storage in dry sand for the same length of time caused them to become very hard and brittle.

The number of cicadas placed in each cell as food has a direct effect on the size of the larval cases and may have some effect on sex, Clausen (3). In one series of observations 47 cells containing small or medium sized larval cases were found to be provisioned with but one cicada. Cells containing large larval cases in the same set of observations were found to have been provisioned with 2 cicadas in 19 cells and with 3 cicadas in 5 cells. Only 2 large larval cases were found with single cicadas and each of these had a large female *T. lyricen*. The average length of 135 larval cases was 3.2 cm. and average width at the widest point was 1.1 cm. The smallest larval case found measured 2.1 cm. in length and .7 cm. in diameter. The largest specimen found was 4.7 cm. in length and 1.6 cm. in diameter.

Soon after the case is completed the larvae shrink in size and the skin appears leathery as contrasted to its thin translucent appearance during feeding, (Fig. 5). The larvae remain in this quiescent stage over winter and begin pupation about one month before emergence, or the latter part of May. Earliest date of pupation of specimens stored out of doors at Dayton in 1939 was May 25. By the first of June all of the approximately 25 larval cases so stored contained well-developed pupae.

The waning of the cicada population in early September marks the end of the active adult cicada killer's life. By early September few adults can be found and before the first frost they are usually absent in the vicinity of colonies. Apparently neither sex overwinters in the adult stage. The life span of adults is remarkably long for such busy insects, covering approximately 65 days, if the dates July 1 and September 1 are considered mean first and last dates.

Since adults are known to feed only for a short time during the mating period the food assimilated must be used with a very high degree of efficiency to permit their tremendous energy output during the active adult life span.

An approximation of the life history of Sphecius by time intervals has been computed from the data assembled and is about as follows:

Egg.....24–48 hours—Late July through August.
Larva.....4–10 days feeding—Late July through August.
270–310 days quiescent—Late July to June 1.
Pupa.....25–30 days—June 1 to July 1.
Adult—60–70 days—July 1 to mid-September.

BEHAVIOR

In size and apparent aggressiveness the cicada killer appears to be one of the most formidable of North American wasps. It is, however, unexpectedly docile. In the course of this study, specimens have been removed from burrows with forceps, banded with colored thread, and released. Others have been knocked to the ground or brushed from captured cicadas with the bare hands. These and other forms of disturbance have never occasioned even a threatened

attack. As has been reported by other observers, however, upon entering a colony, an intruder is sometimes approached in a businesslike manner but with no actual attack resulting.

That Sphecius can and will sting has never been doubted. This was ably demonstrated to one of the writers by a large specimen during capture. The sting penetrated the flesh close to the tip of his right index finger. An initial sharp pain was followed by numbness, a slight swelling, and stiffness which lasted for about a week.

Throughout the summer and during mating activity, the male Sphecius is very aggressive and vigorously pursues various insects and even inanimate objects tossed near his perch, as well as females of the species. In one instance a Sphecius was observed to chase an English sparrow which chanced to fly within 25 feet of his perch. There are some indications that a rather well-defined territory is established by the male, within which all intruders are investigated in a vigorous manner. This territory may well represent the visual limits exciting response in this insect. These guarding activities are not confined to the males, however, as large females have been observed to exhibit somewhat similar behavior.

SOCIAL AND SOLITARY HABITS

The cicada killers are generally considered to be solitary wasps. Nevertheless, they exhibit certain traits of the social insects that are of particular interest. The most obvious of these is their habit of living in colonies made up of individual burrows.

On some occasions more than one female will utilize the same burrow. At the colony in Licking County a marked female was observed freely to enter and leave within a few minutes four different burrows, which were being used by unmarked females. Upon occasion two females have been observed to pass at a burrow entrance, one leaving and the other entering. No show of antagonism was apparent between them. In the same colony 2 females, each in a different cell within the same burrow and each with a cicada on which an egg had been laid, were found August 13, 1940, when one of the writers and Robert Paton were digging out the burrow. On the same date we were able to transfer cicada-laden wasps from the burrow entrance, where they landed, to nearby burrows. When this was done the new burrows were entered immediately. A similar observation was made at the same colony in 1938.

Smith (19), in reporting on a colony of approximately 50 burrows in Philadelphia, Pennsylvania, said that 40 or more individuals were removed without making a noticeable decrease in the number of individuals flying about. Since the sex ratio probably slightly favors females it is apparent that in this colony there must have been many more females than there were burrows.

Observations made to date have not made clear how frequently these apparently social habits occur. It would appear, however, that the habits of this insect are not strictly solitary.

MORTALITY

After larval cases have been formed, losses of Sphecius from natural causes are apparently very low during the normal life span. Losses, however, are very high between the time the eggs are laid and the larval cases are formed. Of 525 cells examined only 201, or 38.28 per cent, contained sound larval cases. The remaining number contained often untouched cicadas, which were frequently covered with mold.

The high mortality is probably due to a number of causes of which only one has been definitely determined. A secondary host relationship was discovered during 1939 between certain flies and Sphecius. Sarcophagid flies observed resting on a mound of earth outside a Sphecius burrow at Cambridge, Ohio, July, 1939, aroused interest in the possibility of such a relationship. Opportunity to investigate was not afforded, however, until similar observations were made in Clermont County, Ohio, in late August of the same year. Subsequent examination of 10 burrows at this location yielded records of one or more cells containing larvae of diptera in the stored cicadas in all but one burrow. Larvae were found in stages of development ranging from newly-hatched maggot clusters to fully-developed puparia.

In some cases both Diptera and the Sphecius larva were feeding on the same cicada. It is evident, from observations made on infested cicadas to which a live Sphecius was still attached, that the fly maggots consumed the available food supply before Sphecius secured sufficient food to complete its development. The smallest number of fly larvae found in a cicada was 16 and the

greatest 27. These larvae, when ready to pupate, ranged from .9 to 1.1 centimeters in length. In the 10 burrows excavated, 87 cells containing cicadas were found. Of these, 26 contained healthy appearing Sphecius larvae, 10 contained cicadas infested with fly larvae, two of which had dead Sphecius larvae still present. The remaining 51 cells contained only dead and often decomposed cicadas. In one burrow containing 9 cells at Washington, Indiana, 2 cells contained healthy Sphecius, one contained cicada and fly larvae and the remaining cells contained only dead cicadas.

One adult fly was captured as it rested on a pile of earth excavated from a burrow. Another was captured in a cell containing diptera puparia and 4 additional adults were obtained from puparia collected. The first two specimens and two of the latter 4 were sent to Mr. David G. Hall of the U. S. National Museum. Mr. Hall's determinations are as follows:

Metopia leucocephala (Rossi), *Sarcophagidae*—2.
Zygobothria sp. (probably *incompta V. d. w.*) *Tachinidae*—1.
Chaetoplagia atripennis Coq.—*Tachinidae*—1.

Mr. Hall stated that the two species of Tachinidae are not known to have any connection with fossorial wasps but that the Sarcophagid is a common parasite of these insects.

In view of the indeterminate status of the flies, further study is needed before more data can be presented. It is sufficient for the present to call attention to the records of their relationship to Sphecius survival.

ECONOMIC IMPORTANCE

The cicada-killer has slight economic importance. In the southern part of the state it has been considered a pest in city lawns, gardens, nurseries, greenhouses, and golf courses. In lawns and on golf courses the unsightly piles of earth removed from the burrows are considered objectionable. In gardens, nurseries, and greenhouses, burrows are sometimes made so close to plants that death to the plant ensues. In nurseries the earth removed from burrows when placed on young seedlings is often deeper than the plant can stand and death results. In addition, colonies of this formidable appearing wasp around city homes and playgrounds cause no little fear to the uninitiated.

In no case has the actual damage reported been of much economic importance. Most of its importance in this respect is properly listed as a nuisance factor. Smith (19), reports complete control of a colony of Sphecius by placing a teaspoonful of calcium cyanide at the entrance of each burrow. Blake Hanan reported, in conversation, that a colony established in a schoolyard at Rocky River, Ohio, was eliminated by a liberal application of old machine oil.

Both of these methods have objectionable features: The first because of the poison hazard; and, the second because of its deleterious effect on vegetation and unsightly appearance. It would seem that, where feasible, frequent watering and aiding vegetation to grow thickly by means of lime and fertilizer applications, if necessary for one or two seasons, would prove an effective control measure because a well-drained soil and scant or no vegetation are two requisites of a successful Sphecius colony.

The major beneficial habit of this wasp is its destruction of cicadas. Although the cicadas taken by Sphecius do not reach serious economic importance in this state, they are a destructive insect. That Sphecius can materially effect the population of cicadas is evident from the number of cicadas stored in individual colonies. In one colony of 373 burrows studied in 1937–38 in Licking County, an average of 30.4 cicadas per burrow were found in 13 carefully excavated burrows selected at random, after provisioning had ceased. On this basis the number of cicadas stored in burrows in the entire colony during 1937 numbered 11,339. The area from which they were taken is not known but since most of the species present were *T. lyricen engelhardti*, which occurs commonly in oak-chestnut forests, they presumably came from forest of this type in the vicinity of the colony. The total

amount of this type of forest within a quarter of a mile radius of the colony is estimated to be considerably less than 50 acres.

Burial of such large numbers of cicadas over a period of years in a limited area has had a noticeable effect on soil conditions. The most evident effect is the incorporation of organic matter in the soil due to the decomposition of the stored cicadas. Loosening of the soil due to digging of burrows and cavities by the adult

TABLE I

Cicadas Collected by Habitat and Species

Date and Locality	Type of Site and Vegetation	Species of Cicada by Number and Sex							
		T. canicularis		*T. chloromera*		*T. linnei*		*T. lyricen engel.*	
		♂	♀	♂	♀	♂	♀	♂	♀
Muskingum Co., Ohio. 8-14-34	Abandoned crop field near old field association and 150 yards from oak hickory woods.			3	1	4	0	1	0
Eden Twp., Licking Co., Ohio, Aug., 1937	Closely grazed pasture adjacent to oak-chestnut forest and old fields.	3	0			8	5	5	21
Glen Este, Clermont Co., Ohio. 8-27-39	Old field—partly grown up with elm, beech-maple woods within 150 yards.			4	15	1	0	0	2
Washington, Indiana. 9-21-39	Nursery—sandy soil 100 yards from old fields; 200 yards from oak-hickory woods.			0	8	0	1		
Dayton, Ohio. 8-30-38	New fill—edge of city limits with many abandoned fields within 100 yards.					0	6		
Totals.....	.....	3	0	7	24	13	12	6	23
	Totals—old field association.			7	24	5	7	1	2
	Totals—Oak Hickory Chestnut association.	3	0			8	5	5	21

wasp is also apparent. Local as these effects are they indicate how myriads of other invertebrates, over a long period of time, have probably added to the formation of vitally important top soil.

To the students of the *Cicadidae*, Sphecius is a valuable ally. By observing the cicada-collecting habits of this insect much can be learned of the distribution and relative abundance of cicadas. It is possible also, to easily obtain specimens of cicadas in good condition by intercepting the burdened wasps as they return to their burrows. Mr. Conrad Roth reports successfully collecting cicadas by plug-

ging Sphecius burrows in the morning and returning later in the day to pick up specimens left by the returning wasps when they found their burrows plugged. Colonizing of Sphecius in localities where cicada-collecting is desired promises a unique method of collecting. An attempt to establish a colony by storing larval cases in a likely place met with moderate success when tried at Dayton, Ohio, in 1939. Of several females released, one established a burrow within a few yards of the place where the larval cases were stored.

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Visual Mechanisms

This volume is the collected papers of The Symposium on *Visual Mechanisms* on the occasion of the Fiftieth Anniversary Celebration of the University of Chicago, September, 1941. The dozen papers represent almost as many different research interests and fields of investigation in vision. Eight of the papers were presented at the Symposium. Four others were added to the Volume by invitation.

Almost any student of vision will find some important and stimulating paper in the list: Hecht on Energy Relations; Krause on the Chemistry of Visual Purple; Wald on the Vitamins *A:* Gellhorn on Anoxia; Bartley, Neurophysiology of the Optic Pathway; Case, Alpha Waves and Structures; Marshall and Talbot, The General Theory of Sensory Acuity; v. Bonin, Garol and McCulloch, Functional Organization of the Occipital Lobe; Polyak, Anatomy of the Retina; Walls, Visual Cells and Their History; Klüver, Functions of the Geniculo-Striate System; Lashley, Cerebral Organization in Vision. Every student of vision should acquaint himself with this volume. Of course some important investigators are absent from the Symposium and could not supply papers, notes the Editor. To hold such a Symposium and to print this volume in wartime is an achievement. The visual literature is richer for it.—*Samuel Renshaw.*

Biological Symposia. Vol. VII (1942) *Visual Mechanisms.* Ed. by Heinrich Klüver. Jacques Cattell Press, Lancaster, Pa. viii+322 pp. $3.25 list.

A NEW CHRYSOBOTHRIS (BUPRESTIDAE: COLEOPTERA)

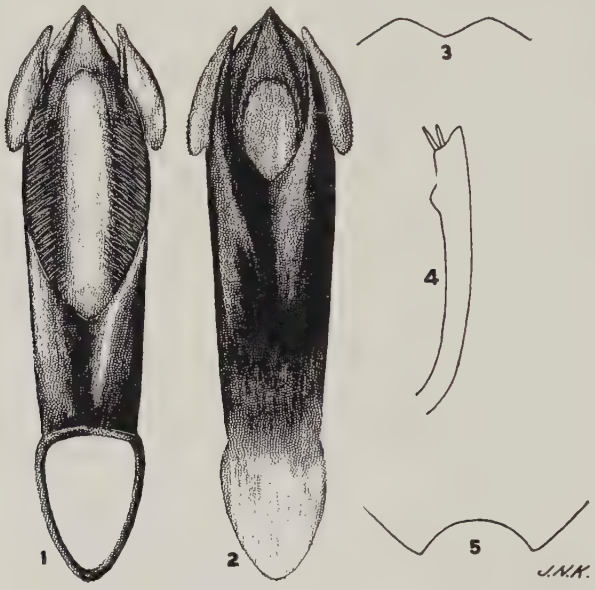
J. N. KNULL
The Ohio State University

Chrysobothris paragrindeliae n. sp.

Male.—Broadly elongate, convex above, dark bronzy brown; front and antennae brilliant green, moderately pubescent throughout.

Head convex; surface lacking callosities or carina, densely coarsely punctured; clypeus deeply emarginate; antennae short, third segment slightly longer than fourth, outer joints wider than long.

Pronotum wider than long, subequal in width at base and apex, widest back of middle; sides broadly rounded; anterior margin sinuate, median lobe broadly rounded; basal margin emarginate each side, median lobe acutely rounded; disk convex, lacking depressions and callosities; surface coarsely punctured, punctures larger than those on head. Scutellum triangular, glabrous.



Chrysobothris paragrindeliae n. sp.
1, Dorsal view male genitalia. 2, Ventral view male genitalia. 3, Clypeus. 4, Anterior tibia. 5, Last visible abdominal sternite.

Elytra wider than widest part of pronotum; sides subparallel to back of middle, then broadly rounded to rounded apices; lateral margins serrulate posteriorly; disk convex, basal depressions deep, humeral depressions shallow; surface densely scabrously punctate; each elytron with two indistinct costae and two foveae.

Abdomen beneath coarsely punctate, each sternite with a smooth callosity on each side along lateral margin; last visible sternite deeply emarginate, lateral margins not serrate. Prosternum with a short broadly rounded lobe in front. Anterior femur with an acute tooth, dentate on outer margin. Anterior tibia arcuate, with obtuse tooth near apex; middle and posterior tibiae straight.

Length—5.2 mm.; width 2 mm.

Described from one male specimen collected at Oak Grove, Calif., June 2, 1941, by D. J. and J. N. Knull, in the collection of the writer.

According to Fisher's arrangement[1] of the genus this species should come after *C. grindeliae* Van D. The structure of the genitalia will separate it from the closely related species.

[1]W. S. Fisher, U. S. D. A. Misc. Pub. 470, pp. 1–274, 1942.

TRANSPIRATION IN AMERICAN HOLLY IN RELATION TO LEAF STRUCTURE

C. A. SWANSON[1]

Although the structural leaf type represented by that of American holly (*Ilex opaca* Ait.) is often regarded as an adaptation to xeric conditions, this species of holly, throughout its native range, occurs most frequently in swamps, stream banks, moist woods, and other similarly mesic to hydro-mesic habitats. It appears that American holly, despite its heavily cuticled and coriaceous leaf, is not a drought-enduring species.

Preliminary experiments made by the writer a number of years ago on potted holly plants are also indicative of a low degree of drought-endurance in this species. When drought conditions were simulated in a green house by not adding water to the soil, the holly leaves soon died, becoming brittle-dry. It was noted that the ordinary yellow coleus, with its thin, parenchymatous leaves, would often survive a considerably longer period of soil desiccation than holly.

Interest was therefore aroused in studying further the water relations of American holly under carefully controlled conditions. Since relatively little experimental work has been done on the influence of structural differences in leaves on transpiration rates, the present investigation has been concerned mainly with this phase of the problem.

MATERIALS AND METHODS

Three series of experiments were carried out, involving different comparative materials and methods.

SERIES I. Potted plants of American holly (*Ilex opaca*) and tobacco (*Nicotiana tabacum* var. White Burley), 15–20 inches and 9–12 inches high respectively, were used in this series of experiments. Comparative records of water-loss in these species were obtained on an automatic transpirometer described by Transeau (1911), and the results calculated in terms of grams of water lost per square decimeter of lower leaf surface. The apparatus and plants were mounted on a slowly rotating table which completed one revolution in about two minutes. The pots were sealed in metal jackets, and provided with stoppered tubes for periodic watering and aeration of the soil.

SERIES II. American holly and yellow coleus (*Coleus blumeii*) were compared in this series. By potting the plants in known weights of soil of known moisture content (30% saturation), and periodically restoring to original weight, a more precise control over the factor of soil water content was effected. The method of experimentation was otherwise essentially the same as in Series I, except that only the cumulative water-loss per day was determined.

SERIES III. In order to eliminate the effect of stem and root conducting systems on the rate of water-loss, the experiments of Series I and II were supplemented by a number of studies using single leaves or small shoots, the cut ends being immersed in water, and necessary precautions taken to safeguard against evaporation from the free water surfaces. The plant parts were cut under water, placed in the containers, and allowed to stand for several hours under a bell-jar, in order to insure an equilibrated internal water balance before making the initial weighing. To maintain uniform environmental conditions, the cuttings were mounted on a slowly rotating table during the course of each experiment in the greenhouse. By this method, the observed water-loss is more nearly a function of leaf structure.

[1]Paper from the Department of Botany, The Ohio State University, No. 452.

RESULTS AND DISCUSSION

Data are tabulated in Table I to show the comparative leaf structure of holly, coleus, and tobacco. The value R is the ratio of internal to external exposed surface of the leaves, and was calculated by Turrell's method (1936). In Table II the data of experiments in Series I and II, are summarized and the average rates of water-loss expressed in terms of per cent relative to holly. The variability of data obtained in Series III precludes a concise summation of the results, but data for three representative experiments are given in Table III.

It is evident from the data in Table II that the rate of water-loss in American holly was on the average higher than in either yellow coleus or tobacco. These

TABLE I

Comparative Leaf Structure

Species	Total Thickness of Leaf	Stomates / sq. mm.		Thickness of Cuticle	R
		Upper	Lower		
Am. Holly	375 μ	0	220	7–10 μ	12.9
Tobacco	182 μ	90	190	1 μ	7.1
Yellow Coleus	155 μ	0	150	1 μ	4.6

TABLE II

Relative Transpiration Rates between Species

Series	Expt.	Species Compared	Average Relative Transpiration	Duration of Experiment
I	1	holly : tobacco	100 : 91	11 hrs.
	2	holly : tobacco	100 : 87	24
	3	holly : tobacco	100 : 95	32
	4	holly : tobacco	100 : 97	6
II	1	holly : coleus	100 : 67	5 hrs.
	2	holly : coleus	100 :104	12
	3	holly : coleus	100 : 88	12

results agree with those of Bergen (1904), Maximov (1929), and others, who have shown that the rate of transpiration in xeromorphic species is often higher than in mesomorphic species.

Turrell (1936) showed that a xeromorphic leaf is characterized by a higher ratio of exposed mesophyll to epidermal surface than a mesomorphic leaf, and suggested that the greater rate of transpiration demonstrated in many xeromorphic species may probably be accounted for in these terms. For *Citrus limonia* and *C. grandis*, Turrell was able to demonstrate a remarkably close correlation. The internal-external surface ratio for *C. limonia* is 1.29 times that of *C. grandis*, and the corresponding ratio of water-loss in rooted cuttings of these species, as calculated from the data of Haas and Halma (1932) was 1.20. This close correlation, however, does not hold for the species used in this investigation; thus, the mesophyll surface exposed per unit external surface in the holly leaves was about 2.8 times as great as that exposed in the coleus leaves, but the average transpiration rate in holly was only 1.2 times as great. Indeed, no close correlation is to be expected,

for too many other variables are always present. The greater transpiration rate in *C. limonia*, for example, may have been due in part to a greater root area relative to the transpiring surface. According to Haas and Halma (1932), *C. limonia* produces more roots per cutting than *C. grandis*.

In order to eliminate such variables as the root/shoot ratio, experiments were carried out using single detached leaves, or small cuttings, as described in the methods. Seventeen experiments comprised this series, the results of which were quite variable. Individual variations within the same species may have been due to differences in stomatal behavior. Marked differences in the per-

TABLE III

Relative Transpiration Rates of Single Detached Leaves

Expt.	Species	Leaf	Water-loss in grams / sq. dm.	Average per sq. dm.	Time
1	Holly	1	1.40	1.4	4–7 p. m.
		2	1.14		
		3	1.46		
		4	1.32		
		5	1.70		
	Coleus	1	0.75	0.9	
		2	0.43		
		3	0.92		
		4	1.32		
		5	....		
2	Holly	1	1.43	1.6	2–5 p. m.
		2	1.28		
		3	1.98		
	Lilac	1	1.86	1.0	Bright sun Temp. 35° C.
		2	0.56		
		3	0.55		
3	Holly	1	0.84	1.5	11 a. m.–7 p. m.
		2	1.70		
		3	1.00		
	Lilac	1	3.10	3.3	Dull, cloudy Temp. 32° C.
		2	3.20		
		3	3.50		

centage of stomates open on different leaves of the same corn plant have been observed by Sayre (1939). Unfortunately, time did not permit an evaluation of this factor in the present experiments.

Evidence for a differential behavior in leaves of different species to varying conditions of light is also indicated. Thus under conditions of high light intensity, holly transpired more rapidly than lilac (*Syringa vulgaris*), but under conditions of lower light intensity (as on cloudy days), less rapidly. This difference probably results from differences in stomatal behavior under the two sets of conditions.

A similar effect of variation in light intensity on the transpiration ratio of *Melissa officinalis* is shown by the experiments of Mittmeyer (1931). Mittmeyer found that in *Asarum* the stomates closed at high light intensities, but remained open in *Melissa*. Under these conditions, the rate of transpiration in *Melissa* exceeded that in *Asarum*, but when the stomates were open in both plants, *Asarum* exceeded *Melissa*.

It seems evident from these experiments and from those of Blaydes (1935) and others, that differences in leaf structure are of little ecological significance in determining differences in transpirational water loss among species. As Shaffner (1928) has pointed out, "the same evolutionary progressions take place whether a group is moving into the water or remaining in the aerial environment." Accordingly, species with thick cuticles, sunken stomates, epidermal hairs, cell mucilages, or a protoplasmic structure capable of enduring desiccation, may be expected to occur in habitats of diverse water relations. From this viewpoint, any correspondence between xeromorphy in plants and drought-endurance would be merely a coincidence.

SUMMARY

The relative rates of transpiration in American holly, tobacco and yellow coleus were determined. Under the same conditions of soil and atmosphere, the holly leaf with its very thick cuticle had an average rate of transpiration which exceeded that of either tobacco or yellow coleus, both with thin cuticles.

The stomatal frequency, when averaged for both upper and lower surfaces, is highest in tobacco, and least in coleus. The internal leaf surfaces of holly, tobacco, and coleus are in the proportion of 12.9, 7.1, and 4.6. No close correlation between relative transpiration rates and the internal surface ratio is evident in these species.

From studies on excised leaves supplied with water, it appears that the relative importance of different leaf structures in affecting the rate of foliar water-loss in different species varies with qualitative and quantitative differences in the environmental conditions to which the leaves are subjected.

The writer wishes to thank Dr. E. N. Transeau for helpful advice in connection with this problem.

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THE EFFECT OF pH ON PURE CULTURES OF EUGLENA MUTABILIS[1]

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The extraordinary acid-tolerance of *Euglena mutabilis* Schmitz has recently been pointed out by Lackey ('38). He found this green flagellate in abundance in numerous pools and streams polluted by acid drainage from coal mines, at acidities as high as pH 1.8. He stated that this one organism was the most characteristic of the highly acid streams.

Stock cultures of *Euglena mutabilis*, contaminated by fungi and bacteria, have been maintained in the protozoology laboratory of Ohio State University for several years at pH 3 or 4, in a medium devised by Kostir and Lotze. The present paper gives the results of a quantitative study on the effect of pH on survival and growth of this organism in pure culture.

For accurate experimental work a pure culture was of course indispensable. A single cell of *Euglena mutabilis* was washed free of bacteria and fungi by migration in a capillary pipette (a micro-modification of the "migration-pipette" method of Glaser and Coria, '30). A pure clone culture was then established for use in the experiments which followed.

METHODS

The following culture medium, a slightly modified form of the Kostir-Lotze medium, was employed in all experiments:

KH_2PO_4	0.25 gm.
KCl	0.25 gm.
$NaHCO_3$	0.25 gm.
$Ca(NO_3)_2$	1.50 gm.
$MgSO_4$	0.50 gm.
$FeCl_3 \cdot 6H_2O$	0.0004 gm.
$MnSO_4$	0.0002 gm.
Aminoids[2]	0.50 gm.
Triple-distilled water	1000 cc.

Adjustment of pH to the various desired levels was made by adding strong solutions of NaOH or H_2SO_4; then the medium was measured into Pyrex tubes (20 x 150 mm.) and autoclaved.

Three separate experiments were performed. In each experiment, all cultures were inoculated from a single source culture of pH 3.4 whose cell concentration was known. The culture tubes were then incubated at room temperature near a north window. After incubation, three cultures at each pH value were used for making cell counts, microscopic examinations of the cells, and pH determinations. The amount of growth was determined by comparing the concentration of cells per cubic centimeter after incubation (X) with the initial cell concentration (X_o), and expressed as ratio of growth (X/X_o).

The customary bacteriological techniques and tests for purity of cultures were employed. Cell counts were made with a Whipple ocular micrometer and a Sedgwick-Rafter counting cell. Determinations of pH were made after inoculation and after incubation, by means of a Hellige colorimetric comparator and a Leeds and Northrup glass electrode. During the experiments the pH of the various culture series remained constant within 0.1 of a pH unit.

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[1]Contributions from the Department of Zoology and Entomology, Ohio State University, No. 115.

This work was done while the writer held a Muellhaupt Scholarship at the Ohio State University, 1939–40.

[2]A casein digestive product of the Arlington Chemical Co., Yonkers, N. Y.

RESULTS

Table I gives the results of three separate experiments. These results show that *Euglena mutabilis* survived for at least 12 days over a range of pH 1.4 to pH 7.9. The total range of growth was from pH 2.1 to pH 7.7, with maximum growth between pH 3.4 and pH 5.4.

In Exp. III, cells from the various culture series were examined at one- or two-day intervals. At pH 0.9 all cells were dead within 24 hours. At pH 1.4 (equivalent to approximately N/25 sulfuric acid) some cells remained alive for as long as 12 days, remaining bright green and showing slight but unmistakable movements during this period. At pH 1.9 some cells remained alive for 13 days.

Euglena mutabilis tolerates a greater hydrogen-ion concentration for survival and for growth than any protozoan in pure culture previously reported. (See tables of pH-growth relationships, Loefer, '35, p. 220; Calkins and Summers, '41, p. 540.)

TABLE I. EFFECT OF pH ON EUGLENA MUTABILIS CULTURES

X_o = initial number living cells per cc.
X = number living cells per cc. after incubation.
X/X_o = ratio of growth.
X_o in Exp. I = 100 cells per cc.
Exp. II = 30 cells per cc.
Exp. III = 335 cells per cc.

pH	X/X_o AT 12 DAYS			X/X_o AT 24 DAYS		
	Exp. I	Exp. II	Exp. III	Exp. I	Exp. II	Exp. III
0.9	.....	——*	——*	.....	——*	——*
1.4	<1	——*	<1	——*	——*	——*
1.9	<1	.....	<1	——*	.....	——*
2.1	.....	.....	20	.....	.....	90
2.4	16	42	.....	74	372	.....
3.4	62	210	.....	165	644	.....
4.0	.....	218	.....	.....	680	.....
4.2	65	.....	.....	158	.....	.....
4.8	.....	193	.....	.....	793	.....
5.4	.....	144	.....	.....	704	.....
6.0	4.8	.....	.....	4.6	.....	.....
7.7	1.9	2.9	.....	2.2	2.1	.....
7.9	.....	<1	.....	.....	——*	.....
8.2	.....	——*	.....	.....	——*	.....

* No living cells present.

SUMMARY

In pure clone culture in an organic medium, *Euglena mutabilis* survived for at least 12 days over a range of pH 1.4 to pH 7.9. Its total range of growth was from pH 2.1 to pH 7.7, with maximum growth between pH 3.4 and pH 5.4.

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